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AN

ESSAY

TOWARDS A CORRECT

THEORY

OF THE

NERVOUS SYSTEM.

BY

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PREFACE.

The leading idea of this work was suggested by the following remarks, which appeared in the American Journal of the Medical Sciences, for August, 1835:

"It may be very possible, that in these neuroses the change, though so slight as to escape our means of detection, does absolutely occur; and yet such is the nature of nervous phenomena, that we must admit that great and extraordinary effects are produced by very slight causes. Do we see any thing like this in nature?—any remarkable alterations in properties depending upon apparently slight causes? We do—we see extraordinary changes taking place in the characters of various inorganic substances, (to which I need not particularly allude,) and there is no reason why the same thing should not occur in organic structures. On considering the doctrine of *Isomerism*, I should be inclined to think that it throws some light on this obscure subject. In chemistry, it is a well-known though singular law, that the properties of two bodies may be essentially different at the same time that their respective component elements are, as far as our knowledge goes, identically the same; and the change, whatever it may be, appears to result, not from the abstraction or removal of any of the component atoms, but from their peculiar juxta-position. Now, it being admitted in chemistry that many bodies having the same constitution

possess totally different properties, and this difference being explained by the different position of their elements, it does not seem strange if the same thing should take place in the phenomena of organized beings; and if this be the case, we have a key towards elucidating the nature of these neuroses, and can conceive how an analogous change —a difference in the arrangement of the molecules of the component parts of the nerves, or their centres—may produce new modifications of their properties, without making any distinct change in their nature, or adding or abstracting a single organic molecule. I am much inclined to adopt the opinion of those who think that, in the neuroses, a peculiar organic change actually takes place, though we cannot demonstrate its existence; because, to reason on the phenomena of animal life, independently of organization, is to plunge blindly into hypothesis, and retrace the errors of an antiquated and exploded school."

The above remarks are by Dr. William Stokes, of Dublin, and are to be found in his Lectures on the Theory and Practice of Physic,—Lecture 23rd.

It has been suggested to me by a friend that, inasmuch as numbers of the medical profession still believe in the doctrine of a vital principle, and also in the identity of nervous influence and the galvanic fluid, I should give these questions a thorough examination. I have done so, as far as my abilities were competent to the task. The result will be found in the Appendix. I have also added a paper upon Absorption.

It will be observed that this work is entitled an *Essay*. It is indeed an attempt—perhaps an unsuccessful one—to bring a large class of phenomena, seemingly the most opposed to the ordinary laws of nature, within the compass of those laws. In this attempt, I am not aware of having violated in any instance the strict rules of inductive logic. I have endeavoured to explain—as far as explanation was possible—known facts, upon well-known and received principles:—I have admitted no hypothesis wherewith to cut the Gordian knot,

when to untie it was impossible. In short, I have endeavoured to follow the rules of philosophizing so well laid down by Sir James McIntosh,* which I will here quote, as the passage is apt to the matter in hand on more than one account.

"The rules of philosophizing," says he, "require that causes should not be multiplied without necessity. Of two explanations, therefore, which give an equally satisfactory account of appearances, that theory is manifestly to be preferred which supposes the smaller number of ultimate and inexplicable principles. The maxim, it is true, is subject to three indispensable conditions. 1. That the principles employed in the explanation should be known really to exist: in which consists the main distinction between hypothesis and theory. Gravity is a principle universally known to exist; ether and a nervous fluid are mere suppositions. 2. That these principles should be known to produce effects *like* those which are ascribed to them in the theory. This is a further distinction between hypothesis and theory; for there are an infinite number of degrees of *likeness*, from the faint resemblances which have led some to fancy that the functions of the nerves depend on electricity, to the remarkable coincidences between the appearances of projectiles on earth, and the movements of the heavenly bodies, which constitutes the Newtonian system; a theory now perfect, though exclusively founded on analogy, and in which one of the classes of phenomena brought together by it is not the subject of direct experience. 3. That it should correspond, if not with all the facts to be explained, at least with so great a majority of them as to render it highly probable that means will in time be found of reconciling it to all. It is only on this ground that the Newtonian system justly claimed the title of a legitimate theory during that long period when it was unable to explain many celestial appearances, before the labours of a century, and the genius of Laplace, at length completed the theory, by adapting it to all the phenomena. A theory may be just before it is complete."

* Progress of Ethical Philosophy, p. 254. American Edition.

It becomes me to add another remark. The affections of the nervous system are of two kinds. The first, consists in a corporeal molecular change; the other, is psychological. It is obvious that though the first may—nay, does always accompany the latter—these affections have nothing in common; they differ in kind, and differ *toto cælo*. To explain *sensation*, *thought*, etc., by corpuscular change in matter is impossible: they are ultimate facts, and like all such, incomprehensible, or, rather, are to be known only in themselves. I beg it be observed, therefore, that it is only with the corporeal change which occurs in the nervous system, that this Essay is concerned.

J. H.

NERVOUS SYSTEM.

CHAPTER I.

ON TRANSMISSION.

The phenomena in which the nervous system is concerned, may all be referred to five classes:

1. Change of nutritive action in the tissues;—which division comprises a set of phenomena, to which no general term, that I know of, has been applied.

2. Muscular motion;—automatic and voluntary.

3. Sensation.

4. The Intellectual Functions.

5. The Emotions;—including under this head, the passions, desires, moral affections, etc.

Instinct seems to consist in the operation of exterior agents upon peculiar organizations of the nervous substance, so as to produce a series of causes and effects ending in certain specific results. In these actions two or more of the above mentioned classes of nervous affections may be implicated.

In each of these classes, one thing is observable: the phenomena are produced by affections of the nervous substance transmitted from other, and sometimes distant, parts. The transmission occurs in all cases, even where the effects are slight; for we cannot change the condition of one particle of the nervous matter without extending the change, more or less, to other parts of the body. The term *Innervation* has been employed

to express in a general manner the phenomena produced by this transmission—a term, the value of which we shall inquire into hereafter.

We have evidence of this transmission of nervous affections in all our sensations and in all our voluntary movements, as it can be proved by experiment that sensations are not experienced where the object comes in contact with the body, for if we divide the nerve no sensation occurs in the organs it connects with the encephalon; and in the same manner we paralyze on the instant all the muscles to which the nerve is distributed.

By pursuing the experiment—that is, by continuing the section towards the spinal cord, and through the cord towards the brain—we shall find that all sensation in the higher animals is experienced in the encephalon; and that there begin those molecular changes in the nervous substance which terminate in voluntary muscular motion.

But besides these obvious instances of change transmitted from one part of the nervous system to another, we have many others to which the same degree of attention has not been given. I refer to those affections of the nerves which modify, and in some cases entirely arrest, the essential actions of life—absorption, nutrition, and secretion.

These affections may proceed directly from the brain; or from the spinal cord previously affected; or from injury to the trunk of a nerve

1. In which the change is transmitted directly from the brain.
   Blushing and all cases of erection from mental emotions.
   Increased perspiration from perplexity or bashfulness.
   Violent passions of the nurse, affecting her milk.
   Loss of breath from sudden joy or grief.
   Pallor of the countenance from sudden grief or anger.
   Sighs from love, etc.
   Diarrhœa from terror, and supra-secretion of urine from anxiety.
   Bleeding at the nose from violent anger.
   Cure of quartan ague from unlooked-for good fortune.
   Tears from grief.

Influence of imitation and enthusiasm, as among religious fanatics, etc.*

2. In which the change is transmitted secondarily from the spinal cord.

Tears from exquisite pain.

Pallor and coldness of the body from local injuries.

Secondary inflammation, such as occur in the stomach from a compound fracture of the leg, or any other local inflammation.

Pallor and cold perspiration produced by metallic poisons.

Effects of blisters on irritable habits.

Effects of cold when applied to certain parts of the body, as the scrotum, producing rigor and consequent reaction.

3. In which the change is transmitted to the tissues in consequence of injury done to the trunk of a nerve.

If the pneumogastric nerves be divided death ensues in a few hours from a lesion produced in the lungs.

Bichat by dividing the nerves going to the testicles, produced inflammation in those organs.†

Magendie divided the fifth pair of nerves within the cranium. Instant loss of sight, violent inflammation of the membranes, subsequent ulceration of the cornea, and total destruction of the eye, were the effects produced.‡

Division of the median nerve in the arm instantly produces coldness, collapse, and cold perspiration in the hand.

Chemical agents act in the same way. Thus Bichat, "I have irritated in a dog the sciatic nerve with nitric acid; the whole

* Rapprochez le temps où toutes les passions sombres, la crainte, la tristesse, le désir de la vengeance, semblait planer sur la France, de celui où la sûreté, l'abondance y appelaient les passions gaies, si naturelles aux Français; rappelez-vous comparativement l'habitude extérieure de tous les corps dans ces deux temps, et vous direz si la nutrition ne reçoit pas l'influence des passions. Ces expressions, *sécher d'envie*, *être rougé de remords*, *être consumé par la tristesse*, etc., n'annoncent elles pas combien les passions modifient le travail nutritif? Bichat Recherches sur la Vie et la Mort.

† Op. cit. p. 507. See also his General Anatomy.—Trans. Vol. i. p. 209.

‡ Journal de Physiologie, tom. iv.

limb was swelled and painful the next day. I have at this time another, the whole of whose fore limb is swelled, because I passed a pin, two days before, through one of the anterior nerves, taking care to entangle some of the nervous filaments."*

Diseases of the nervous trunks, tumours pressing upon them, etc., produce like effects.†

In wounds of the spinal cord, all the parts below the seat of lesion are not only paralyzed—that is, they not only lose their sensibility and the faculty of moving at the command of the will, but their nutrition is seriously affected. Hence, ulceration of the hips, inflammation of the mucous membrane of the bladder, etc., from wounds of the spinal marrow.

Another thing is to be taken notice of:—the effects, though more apparent in the tissues, are not confined to them. The transmission is not only towards the periphery, but also towards the nervous centres. Thus when a large nerve is divided, cold perspiration, particularly in delicate habits, is experienced over the whole body, and sometimes is even attended with syncope. W. Philips demonstrated the same principle by experiments wherein lesions of the spinal cord at the lumbar vertebræ caused impairment of the digestive process in the stomach.‡

The sympathetic does not differ in this respect from the cerebro-spinal nerves. Dupuy excised the superior cervical ganglion in horses;—the results are thus summed up by Magendie: "The phenomena which are manifested after the extirpation of this ganglion are, contraction of the pupils, redness of the conjunctiva, general emaciation accompanied with anasarca of the limbs and eruption of the itch which ends by affecting the whole cutaneous surface."§

To this I will add the following experiments made by Professor Mayer of Bonn, which I find copied into my note-book but without mention of the work from which they are quoted.

* General Anatomy, vol. i. p. 209—11.

† Vide Andral's Pathological Anatomy, vol. ii.—See also Sir C. Bell's work on the nerves (last edition.)

‡ Experimental Inquiry,—exp. 58, 59 and 60.

§ Notes to Bichat's Recherches sur la Vie, &c.

Of eighteen experiments on dogs, horses, and pigeons, the following are the results.

In some cases a division of the cervical portion of the sympathetic was followed by redness and inflammation of the conjunctiva.

The same morbid changes in most cases followed a division of the pneumogastric nerve.

The sympathetic and pneumogastric having both been divided, a very intense inflammation of the eye took place, and extended to the interior of the organ.

When a ligature was placed on the carotid, pneumogastric and sympathetic, an effusion took place from the anterior surface of the iris, the pupil was closed by a false membrane, and the cornea ulcerated.

I mention these facts because the sympathetic is supposed by some writers to be altogether distinct from the cerebro-spinal nerve, and not to partake of the property of transmitting affections from the periphery to the nervous centres, and the reverse. If this were the case, they would be altogether useless, since a nerve is a conductor merely and performs no other function than that of transmitting impressions;—but a little observation will put this to rest.

Affections of the brain are transmitted to the viscera; thus we see diarrhœa, supra-secretion of urine, jaundice, &c., in consequence of violent emotions; and the viscera react upon the brain and other portions of the nervous system, a fact exemplified every day in health and disease. Now, some of the viscera, as the kidneys and small intestines, receive no other nerves than the sympathetic.

These nerves then are only so far independent of the brain; as observation will warrant us to decide. They are independent so far, that no exertion of the will affects the muscles supplied by them; so far, that slight impressions made on the tissues with which they communicate, are not *in health* transmitted to the sensorium. They owe this difference between them and the spinal nerves to their organization; but as few individuals are precisely alike in regard to their nervous system, cases have

now and then occurred in which the constitution of these nerves seems to have approached very closely that of the cerebro-spinal, for individuals have lived who possessed some power over the contractions of the heart, and others, who could vomit at pleasure.

Certain emotions, as likewise irritations made upon the base of the brain, spinal cord, or nerves, may also affect the muscles, producing involuntary movements.* This differs from the phenomena just mentioned, merely in the fact, that in one case, a peculiar and distinct tissue (the muscular) is implicated; and in the other, that the tissues generally are affected.

The causes which produce transmission are therefore of three kinds,—moral, chemical, and mechanical. But that it may take place, integrity of the nerve is absolutely necessary. Division, or a ligature, or disorganization by disease, etc., destroys this property utterly, but only at the point where the lesion is inflicted, for if we irritate the nerve *below* that point, convulsions of the muscles ensue; and if *above*, sensation occurs.

The property of transmission evidently depends, therefore, on two things;—the chemical constitution of the nervous substance, and a peculiar arrangement of its molecules, since when that arrangement is destroyed, or the chemical constitution changed, the property is lost.

At the moment that the nervous substance is disorganized transmission always takes place,† but the effects produced will vary according to many circumstances, among others, to the

* Thus we have vomiting at sight of disgusting objects; contraction of the occipito-frontalis from terror; arrest of hiccough by exciting the attention, etc. The expression of the different passions on the countenance is another instance in point.

† Transmission, I believe, occurs whenever an impression is made on the nervous substance; but the effects may be so slight and transient as to escape observation. An ulcer on the leg will change its condition in a few hours from a slight irregularity in diet, from intermittent fever, or from mental emotions. Now it is plain that if no ulcer existed on the leg, there would be no evidence of a change having taken place in the condition of its nerves. But a change has occurred in the nervous substance of the cord, and has been transmitted to the leg, as the state of the ulcer proves.

chemical character of the foreign body. Thus, when a ligature is placed on the trunk of a nerve, or when it is touched with caustic potash or strong acids, the muscles, connected with it, are convulsed; but no such effects are produced when narcotics are applied to the nervous substance even though it be upon the brain or spinal cord. This is the more singular, since though narcotics applied to the nervous substance completely destroy its property of transmission at the point where the application is made, yet taken into the circulation many of them act upon the spinal cord and produce violent general convulsions.

The effects produced by transmission will also vary according to the portion of the nervous system first affected.

For it can be easily proved that the nerves, connected with the anterior and posterior columns of the spinal marrow, perform very different functions. In short, the former are nerves of motion, and the latter, nerves of sensation;—the one set transmit *from* the encephalon; the other, *towards* it.

Here an interesting question arises. Is transmission in these two sets of nerves ever reversed? That is, do the nerves of motion ever transmit impressions to the centres; and the nerves of sensation, to the periphery?

In the present state of our knowledge, it is impossible to give a positive answer to the question. For it is not known whether the nerves coming from the anterior columns of the spinal cord are distributed exclusively to the muscles or not. Unquestionably nerves which run to other tissues than the muscles propagate impressions towards the periphery. The lungs are affected by division of the pneumogastric nerves; the eye is inflamed by division of the fifth pair; the skin of the cheek is affected in the phenomena of blushing, etc., etc., and beyond doubt, these organs receive nerves of sensation. But do they receive none from the anterior column of the spinal marrow?

There is one circumstance which would lead us to suppose that the transmission is never reversed. If the posterior root of a spinal nerve severed from the cord, be galvanized by passing a current across it, no contractions ensue in any of the muscles; and yet, it can easily be demonstrated that the muscles receive

nerves of sensation. But again it may be replied, that to produce muscular contraction, there is required not a transmission of change merely, but a transmission of a *peculiar* change in the nervous substance. We have just seen that laudanum, etc., applied to a nerve causes no contractions, though it unfits the nerve for the performance of its functions; and we know from other sources that spirit of wine applied to the brain or spinal cord produces no effect on the muscles of voluntary motion, though it powerfully affects the heart;* showing thereby that transmission has occurred.

The probability therefore seems to be, that not the muscles only but all the tissues of the body receive nerves from the anterior column of the cord as well as those of sensation; but the point can only be settled by making careful experiments on the two roots of the spinal nerves and observing the effects on the tissues.

The nerves of special sense (the olfactory, optic and auditory) when cut, irritated, lacerated, etc., cause no pain. They therefore differ from the other nerves of sensation.

The sympathetic differs from the cerebro-spinal nerves in never propagating impressions made upon the organs supplied by it, except in cases of disease. The will, too, exercises no control over the muscles supplied by the sympathetic; nor does irritation of this nerve or the central ganglia produce the same effects on the organic muscles as upon those supplied by the cerebro-spinal nerves. The muscles of organic life are peculiar in their mode of contraction; never displaying the brisk, quick, rapid succession of contraction and relaxation of the voluntary muscles, but constricting themselves in a slow, gradual manner, and in a rythmic order of succession.

The spinal cord, with regard to transmission, differs in some important respects from the nerves. The nerves are conductors merely; they never transmit the affection of one fibril to another, though both be enclosed in the same neurilema and lie in contact. But in the spinal cord, the transmission from the nerves

* Wilson Philip, Experimental Inquiry.

of sensation to the nerves of motion often occurs even in health. This can be easily proved by galvanizing the posterior root of one of the spinal nerves. If the nerves be connected with the cord, the muscles are convulsed, though to be sure not to the same degree as when the anterior root is galvanized. That the affection is really transmitted along the anterior roots to the muscles may be proved by dividing those roots, or by severing the posterior root from the cord; in either of which cases, no contractions of the muscles ensue. This is the reflex action of Mr. Hall, and it occurs only in the medulla spinalis and oblongata. The phenomena occur as follows: a change is made in the nervous substance of the nerves of sensation; this change is propagated to the spinal cord; the motor nerve is next affected; that affection is transmitted to the muscles, and they contract.*

This reflex action never occurs when the nerve upon which the impression has been made is severed from the cord; but it may take place in every portion of the cord. Thus, with frogs, whose excitability has been increased by the administration of strychnine, the slightest touch on the surface of the body will throw the muscles into convulsion, which will extend to all the muscles of animal life. But if the cord be divided transversely, those muscles supplied with nerves from the cord, beyond the point of section, remain quiescent; if divided longitudinally, only one half of the body is agitated; if divided longitudinally above and below, so as to leave a small portion towards the middle of the body, intact, it is the same as though the cord were uninjured;—the muscles are convulsed over the whole body.†

It is obvious from this narration of facts, that the cord differs in another particular from the nerves. The nerves of sensation transmit *to*, the nerves of motion *from*, the encephalon; at least it is but problematical that they ever propagate their impressions in the reverse directions. But the spinal cord transmits its

* The movements of the pharyngeal muscles in deglutition, those of the diaphragm in sneezing, hiccough, vomiting, etc., are all caused by reflex action.

† See Volkmann's Experiments on Reflex Motions. Medico-Chirurgical Review, July, 1838.

affections in every direction;—no matter where the impression is made, general convulsions of the muscles ensue.

Impressions made on the sympathetic nerve may also, as well as those made on the spinal nerves, be reflected to other organs through the medium of the spinal marrow. Thus convulsions occur in children from the irritation of worms upon the alimentary canal.

This reflex action of the cord does not implicate the muscles alone—any more than when the trunk of a nerve is divided or a ligature is placed upon it, the muscles are alone affected. *All* the tissues are affected; but as the effects are more striking in the muscles, more attention is directed to them. I have already mentioned several instances—(such as tears from exquisite pain, etc.,) in which the actions of nutrition were altered in the tissues through the medium of the spinal marrow. In truth, every case of fever from a local injury is but a manifestation of reflex action from the spinal cord.

The spinal cord ends in the medulla oblongata, whither all impressions are transmitted, and where sensation is experienced. The medulla oblongata transmits those molecular changes which accompany the exercise of the will, to the spinal cord; and those which accompany sensation, to the brain. It also shares with the spinal cord the property of reflex action, and is essential to the function of respiration.

The brain (cerebrum) transmits its affections to the medulla oblongata, as when volition is exercised in consequence of intellectual operations. The affections of the medulla thus received may be radiated on the nerves of smell, hearing and vision, rendering their perception duller or more acute, or perverting them.

It has already been mentioned that spirit of wine applied to the brain quickens the action of the heart, but does not affect the voluntary muscles. So likewise mechanical lesions of the cerebrum have no effect on the muscles of animal life; nor do they cause sensation.

Of the cerebellum we know but little, except, that where wounds are inflicted upon it, very marked and singular effects

are produced, when the animal attempts to use its voluntary muscles.

To sum up: *to* the spinal marrow, impressions are transmitted along the nerves;—*from* the spinal cord thus affected, the change is transmitted to the encephalon and rest of the body. The spinal cord, therefore, may be regarded as the centre of the nervous system;—its radii being the medulla oblongata, nerves of special sense, cerebellum and cerebrum on one side, in opposition to the nerves of motion and general sensation on the other.

It is by this property of transmission that the nervous system is to be regarded as a continuous whole, but in no other sense; for the nervous substance is not homogeneous, since identity of organization would imply identity of function. But we know that different portions of the nervous substance perform very different functions.

CHAPTER II.

NATURE OF THE CHANGE UNDERGONE.

We must again call attention to the fact, that in any phenomenon produced by nervous transmissions, the change undergone in the nervous substance is peculiar to the particular case. To produce any given effect, it does not require transmission merely, but transmission of a *peculiar* kind. The brain, for instance, transmits certain affections to the medulla oblongata; the will is exerted, and the muscles contract. But powerful emotions, mechanical lesions of the brain, etc., produce no contractions of the voluntary muscles, yet violently affect the heart, cheeks, organs of generation, etc., etc. So again, irritation reflected from the cord, affects the muscles in certain cases but not in others. For instance, they are not convulsed in cases of fever ensuing upon local inflammations, though the change in the condition of the nervous substance has beyond question been reflected upon them as well as the other tissues.

To point out the general nature of the change undergone, the mode in which that change is propagated to, and from the spinal cord, together with a generalization of the manner in which the effects upon the tissues are produced, is therefore, all, that in the present state of science we can hope to accomplish.

The change produced in the nervous substance by impressions of any kind whatsoever, is evidently a *chemical* one.

Because the essential actions of life—those actions which ge-

neralized and taken together *constitute* what we understand by the term, "*Life*," and which are altered, increased, or diminished by nervous transmissions, are themselves of a chemical character.

For, it is evident, that the nature of life must be sought for in that in which all living beings agree; and observation points out to us, that they agree in converting a certain liquid (the nutritive fluid) into the solids which compose the frame work of the being, and in no other point whatever. This process of assimilation occurs in all living beings, but is more rapid and complicated in the more highly organized classes.

As the nutritive fluid undergoes in this process a real transformation, and as every molecule is implicated in this intestine corpuscular mutation, the process is evidently of a chemical nature, however at a loss we may be to imitate or even account for particular results.*

The results of this intestine action between the solids and nutritive fluid are evidenced in the development, from the embryotic state of the form proper to the species;—in its growth to puberty;—in the maintenance of the volume and weight of the body in adult life; and in animals, in the gradual decay of old age.† Disease is the perversion of nutritive action;—death, its cessation and the commencement of another kind of chemical change.

While this action goes on, a portion of the nutritive fluid becomes solidified; but another portion, (mixed in animals perhaps with a part of the old solids, reconverted to fluids,) is thrown outwardly and appears as a *secretion;* for there are not two different processes, one nutritive, and the other, secernent. Assimilation and secretion are but different results of the same chemical operations.

Unorganized solids increase or diminish in volume at their sur-

* The theory of a "Vital Force," as an entity *per se*, is as absurd in logic as it is gratuitous and hypothetical in philosophy. It is perfectly on a par, and not a whit more respectable than the phlogiston of the chemists.

† "Death appears to be a necessary consequence of life, which by its own actions, insensibly alters the structure of the body, so as to render its continuance impossible."—*Cuvier*, *Règne Animal*, *Tome*, *I.*

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faces : particles may be added to the common mass, or they may be abstracted. But observation shows us that such is not the way in which organic beings are developed, waste away, or are sustained. We know that the particles of the nutritive fluid are deposited in the very interior of the solids, and are afterwards thence removed : the tissues therefore receive additions to their substance, not by *juxta-position*, but by *intus-susceptio.*

But that the nutritive fluid may act upon the solids, so as to be assimilated, it is plain, that it must penetrate them intermolecularly, that is, the molecules of the fluid must come in contact with those of the solids, for in no other way can we imagine the chemical change to occur. Hence, *porosity* is a *sine qua non* in all living beings ; and hence too, *absorption* is an indispensable prerequisite to nutritive action.

Substances are not absorbed into a living being (as was once supposed,) by any vessels whatever;—lymphatics or veins. These vessels are but the *channels* of conduction. Absorption occurs in consequence of a general law of nature;—the attraction of matter for matter.

The particles of which any body is composed, are not, as is well known, in absolute contact; all bodies, for example, are penetrable by caloric. But the organic solids not only permit caloric to penetrate between their molecules, but their particles are so far apart that fluids can also inter-penetrate them. This occurs by the same laws that enable the particles of a salt to inter-penetrate those of a fluid.

When a solid absorbs a fluid, the rapidity of the absorption will depend upon two things:—first, the relation which the solid has to the fluid ; for the forces with which bodies attract each other, are different in different substances ; and secondly, upon the rapidity with which the fluid is removed away from the absorbing body.

Now we have seen from the experiments of Bichat, Majendie, and others, besides also from pathological observations, that mere division of a nerve, or disease of it, or compression by a ligature, will produce disease in the tissues with which it is connected. In

short, nutrition is perverted, and as that is a chemical action, the cause of perversion must also be chemical.

It is plain, also, that when a change occurs in nutritive action, one of two things must occur; either the nutritive fluid must change its chemical constitution, or the tissues must alter theirs. The nerves, however, have no connexion with the blood, and with the tissues they have, therefore the inference is plain, direct, and inevitable :—the nerves by their transmissions must affect the chemical constitution of the tissues, and they can only do so, by being first altered in their own.

Furthermore, when bodies change their cohesive powers, as we know the muscles do when they contract, there must be some molecular change to produce the effect. For if every corpuscle in the muscle should remain chemically the same, how is it possible to imagine the contraction to occur. There must be some cause of disturbance in the sphere of cohesive molecular attraction ; and the only circumstance to which we can rationally attribute the contraction is change of chemical constitution in some portions of the molecules which make up the organ.

That a chemical change occurs in the nervous substance was suggested by Cuvier, though he was disposed to think the transmission affected by the agency of an imponderable fluid. "All contraction," says he, "and generally speaking, every change of dimension in nature, is produced by a change of chemical composition, though it merely consists in the ebbing or flowing of an imponderable fluid."* And again : "the causes which act on the nervous fluid seem to change its composition; this appears the more likely, as the action of the nerves becomes weakened by continuance, as if the fluid needed the resumption of its primitive composition, to fit it for a fresh alteration."† And again :—"There are phenomena which show that the general susceptibility of the nerves, for receiving sensations, may vary in consequence of causes external to the nerves themselves, and which can only operate by altering their substance. Certain medicines weaken or revive that susceptibility ;—inflammation frequently

* Règne Animal, Tome, i. † ibid.

increases it to an excessive degree. Does this take place in consequence of an increased secretion of the nervous matter? The most remarkable change that occurs in the susceptibility of the nerves is sleep. It is not unnatural to suppose that this change may be occasioned by the temporary loss of the substance which is essentially sensitive. But how does it happen that sleep depends, in a certain degree, on the will? Why do we awake suddenly, or from causes which do not appear calculated to restore that substance? Why does cold produce sleep? From these observations may it not rather be supposed that this state is the effect of a change in the chemical nature of the nervous substance?"*

For my own part, I conceive that every one of the facts mentioned in the foregoing chapter, to show that change in the condition of any part of the nervous substance affects the process of nutrition in distant tissues; as likewise, *à fortiori*, those we are yet to consider when we come to the effects produced by nervous transmissions, will have the weight of proof in this matter. How, in few words, can we account for the extraordinary effects, produced on the nervous system, by prussic acid, opium, digitalis, and other narcotics, unless we grant they act chemically on the nervous matter. Just, too, as we ought to expect, different substances act in different ways on the nerves: alcohol, ammonia, quinine, and so on throughout the materia medica; produce, all of them, their own peculiar effects. And not only so, these effects vary just as the nervous substance changes its state. *Quinine*, for instance, has powerful effects on some persons; on others, it has scarcely any. In some diseases we cannot employ those substances which would be of benefit in health or in another disease.

That a chemical agent should affect the constitution of another substance, cannot however, be matter of surprise; but it is surprising how mere *mechanical* agents, how mere impressions which can produce no immediate effect on the nervous substance, other than displacing its particles, should also change its chemi-

* Lectures on comparative anatomy, vol. ii., translation.

cal constitution. And yet we know that mechanical agents do this; for what is the death-like paleness, the coldness and clammy perspiration, which ensue almost immediately after the infliction of a gun-shot wound, but the evidence of altered nutritive action in the tissues, brought about by nervous affections transmitted from the seat of injury?

The problem, therefore, is—first, to explain how mere motion among the particles of a substance may be accompanied by change of chemical constitution; and secondly, how this change once produced is transmitted to distant parts.

According to the prevailing theory of the schools, transmission is produced by the agency of an imponderable fluid secreted by the nervous centres, and moving by flux and reflux to, and from them, along the nerves. This theory cannot possibly be true;—if for no other, for the following reasons.

We have shown from the experiments of Bichat, Majendie and others, that inflammation takes place in the tissues whose nerves have been divided in the trunk. Thus Majendie destroyed the eye through inflammation and ulceration simply by dividing the fifth pair within the cranium. Bichat produced inflammation of the testicles by dividing their nerves. Division of the pneumogastric nerve on *one* side will cause pneumonia, etc., etc.

Now a close attention to facts will show that inflammation is not the primary lesion produced by serious injuries inflicted on the nerves. A state precisely opposite precedes the formation of inflammation. In short, we have pallor, subsidence and contraction of the tissues, coldness, and loss of sensibility; before redness, tumefaction, increased heat, and exalted sensibility make their appearance. We have the cold stage before the hot.

Inflamed parts are in a state of irritation, or, if you choose, of exalted vitality. Upon the theory then, of an ebb and flow, of a flux and reflux along the nerves, what causes the irritation? Certainly not the accumulation of an imponderable fluid in the diseased tissues, derived from the nervous centres; for the communication is cut off. And if it be contended that the nerve,

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thus severed from the centres, is sufficient for the secretion of such a fluid, what causes this super-abundant secretion? Irritation:—but on such a supposition, what is irritation itself; what is its origin;—how is it produced;—and what is the cause of its production?

In order to give what I consider correct notions on the nature of the change undergone and the mode of its transmission, I must review, somewhat at length, the principles of natural philosophy and chemistry;—sciences which seem at first to be irrelevant to the matter in hand, but which, in truth, are absolutely necessary to a right understanding of physiology. The next chapter, therefore, will be devoted to this subject.

CHAPTER III.

ON THE PRINCIPLES OF NATURAL PHILOSOPHY AND CHEMISTRY.

Attraction.

When we fix upon any point in space there are two relations which that point may bear to a moving body: the motion may be *towards* it, or *from* it. All other modes of motion can be decomposed into these.

The tendency of one body to move towards another, without the intervention of a propelling force is called attraction. This tendency is exerted among bodies whether in motion or at rest; though certainly the approach of one body to another is the more striking manifestation of it. The tendency to recede is called repulsion.

Attraction and repulsion are ultimate facts in nature, for which no reason whatever can be assigned.

Attraction is displayed in several ways, and is known by different names, according to the circumstances which modify its development. The two great divisions are into attraction of aggregation and chemical affinity.

Aggregation.

When a portion of matter approaches another, similar or dissimilar, without an essential change of properties being the result of the conjunction, the attraction is called aggregation. The force of aggregation is greatest in solids, less in liquids,

and least in gases;—and these three classes of substances also differ among themselves in this respect; the cohesive force of some solids being far greater than that of others, etc.

Aggregation is evidenced under many circumstances, and of course, is presented before us with various modifications. It is manifested,

1. Amongst the particles of homogeneous matter; forming solids, liquids, or gases, according to the different relations which a body bears to caloric.

2. Between a solid and a liquid;—and in two modes:—*a*. Where the cohesive attraction of the molecules of the solid for each other is greater than the reciprocal attractions of the liquid and solid. The rise of liquids in capillary tubes;—the absorption of liquids by sponge, dry bladder, wood, etc., etc., are instances in point. *b*. Where the attraction of the liquid and solid is greater than that of the solid particles for each other. All cases of solution of a solid in a liquid are examples of this class.

3. Between two liquids, e. g., the uniform admixture of alcohol and water;—of acetic acid and water, etc., etc., in spite of considerable difference with respect to specific gravity.

4. Between two gases, e. g., the uniform admixture of carbonic acid gas and hydrogen, though the first be of so much greater specific gravity.

5. Between a gas and a liquid, e. g., evaporation; the absorption of atmospheric air by water; absorption of ammoniacal gas, etc., by water.

6. Between a gas and a solid, e. g., the absorption of gases by charcoal, dry bladder, caoutchouc, etc., etc.

7. Between two solids, which, however, retain their primitive forms after conjunction, through the paramount attraction exerted among the particles of each. Dust which adheres to the surface of a mirror; corks that approach the sides, when floating in a basin of water, etc., are examples in point.

This last variety when exerted between other bodies and the earth, is called *gravity* or the *attraction* of *gravitation*. The immense mass of matter composing the earth makes it for us a point of reference with regard to all the separate bodies on its

surface. Attraction in all cases is mutual, so that, if the earth exerts an attractive force on bodies removed from its surface, those bodies also exert the same upon the earth. The difference, however, is so immense that the effect upon the earth cannot be appreciated, and is therefore disregarded.

It must also be obvious, that the attraction exerted by the planets on the sun, by the sun on the planets, and by the planets on each other, is merely the attraction of matter for matter, as exerted between two or more solids.

It is worthy of notice, that several of the modes of aggregation are frequently expressed by the words *cohesion*, *adhesion*, solution, imbibition, absorption, etc. These terms, though exceedingly convenient, are worse than useless as philosophical distinctions.

Chemical Affinity.

When particles of heterogeneous matter approach each other, it frequently happens, that their conjunction results in the formation of a compound substance possessing entirely different properties from its components. This species of attraction, is *chemical affinity.*

What is the essential difference between affinity and aggregation? In a crystal of blue vitriol, there are particles of copper, oxygen, and sulphur; and however minutely I may divide the mass—even by solution—I shall still find, upon analysis, these particles in conjunction. The mass is therefore homogeneous; and though I may break up the cohesion by solution, I cannot, by the same process, separate the component or elementary particles. There are evidently, then, two species of attractive forces in the crystal; to wit, cohesion and chemical affinity. In what does the difference consist?

We must grant, in the first place, that these elementary substances have mutually penetrated each other, so as to exist throughout the mass in certain definite proportions, and these proportions form what may be termed "compound particles," separated from each other in the dissolution of the salt. Now

what do we mean by a solution? We mean merely that the particles of the solid body are taken up by those of the liquid, and held suspended therein by the force of reciprocal attraction. The particles of the liquid and solid are in juxta-position, but they can easily be separated;—in some cases, by the mere power of gravity; in others, by evaporation; in others, by the addition of some third substance. The attraction between the particles is slight, and when a third substance comes in contact with them, *they do not act conjointly upon it.* But in a *chemical* compound the elementary substances do and must act conjointly in undergoing any chemical change.* Hence it is that compounds present properties so very different from their components. For suppose another element (e. g., iron) be presented to the blue vitriol, in such a manner that the compound particles be at liberty to obey their affinities uncontrolled by cohesion;—in a word, suppose the iron presented to the blue vitriol in solution. Now in this case, it is not the sulphur, nor the oxygen, nor the copper, that acts alone upon the iron, but *all three at the same instant of time* act upon it. Hence it follows of necessity that the results must be different;—in short, the compound must necessarily display properties different from the individual components.

A suggestion may be made, that in a binary compound, such as *water*, the properties should be in a medium of those of its elements. But this, as must be evident, can only be legitimately inferred of substances in solution; that is, where their condition is not essentially changed. We know nothing of the properties of any body except from observation; for between cause and effect there is no necessary connexion discoverable. We know

* "In chemistry, the compounds are the very elements themselves. When any two substances present together, vanish, as it were, from our view, and a third substance, whether like or unlike to either of the former, presents itself in their place, we believe this third substance, however dissimilar it may appear, to be only the coexistence of the two others; and indeed, since we have no reason to believe that any change takes place in the number of the corpuscules of which our planet is composed, the whole series of its corpuscular changes can be only new combinations of particles that existed before."—*Brown's Philosophy*, vol. 1. Sect. xxxiii.

the properties of oxygen, for instance, only so far as they have been revealed by observation and experiment. But whenever a substance is placed under an essential change of circumstances, its properties are changed; which, indeed, is merely saying that its modes of action on other bodies are altered. Therefore, until we have placed a substance under all possible circumstances (which is impracticable) we shall never know what all its properties are. The conjunction of two elements in chemical union, supposes each of them placed in circumstances entirely novel; therefore, what properties the compound (for we can no longer consider the operation of separate elements) may present, it is impossible to foretel. The affinities of oxygen in a drop of water are not exerted alone, but conjointly with, and influenced by, the affinities of hydrogen.

From this it appears that cohesion between heterogeneous substances and chemical affinity differ merely in this, that the particles in the one case are in more intimate union and held together by stronger powers of attraction than in the other, so that when a third body is presented they act conjointly upon that body:—in short, they differ merely in degree.* But much will depend upon the substance presented; hence we see in certain cases a great liability to decomposition; and in others, the particles of the solvent entering as one of the components of the new substance produced.

Nature does not pursue her operations within those well defined lines and limitations—those classifications and systems,

* This is the opinion of the celebrated chemist M. Dumas, who expresses himself as follows.

"Faut-il voir là trois forces distinctes: la cohésion, la force de dissolution et l'affinité, ou bien la même force modifiée? Cette dernieré opinion est la plus simple. N'est ce pas aussi celle que conduit à adopter an examen attentif de la question?

"La cohésion s'exerce entre des particules *similaires;* elle est faible et sans limit apparente. La force de dissolution s'exerce de préférence sur des particules *analogues;* elle est plus forte que la cohésion, et si elle s'exerce d'une manière indéfinie, c'est seulement entre certaines limites. L'affinité s'exerce surtout entre des particules très *dissemblables;* elle est très énergique, présente des limites tranchées et donne des produits toujours definis."—*Leçons sur la Philosophie Chimique*, p. 389, *et sub.*

which the necessities of man force him to mark out. We have a map of the sciences in every different compartment of which, we have fixed certain facts and subjects of study. But nature has no such chart. Her operations are variously infinite, and run progressively by indefinite degrees through all the sciences. Mix oxygen and nitrogen gases together and we shall have a solution of one in the other, but without change of properties, evolution of caloric, or change of bulk. Mix pure alcohol and water together and we shall have diminution of volume and evolution of caloric. With sulphuric acid and water we shall have a greater diminution of bulk, together with a greater increase of temperature: and with ammoniacal and muriatic acid gas, we shall have an entire change of form and properties.

Now in all these instances what do we observe more than different degrees in the force by which the particles of the substances are held together? If the molecules are kept together in such a manner that only *one* kind act upon a third substance, it is a solution; if they act *conjointly* on that third substance, it is a chemical union. But where shall we fix the limits between the two? Assuredly it cannot be done;—as well might we attempt to designate where one colour of the rainbow ends and another begins.

*Isomerism.**

In what we have said above we have a ready explanation of some singular facts which modern chemistry has brought to light. It would occur to every one as a necessary consequence that when the same elements unite in the same ratio, the same compound must be invariably produced;—yet such is not the fact, as the following examples will show:

Racemic acid Tartaric acid	chem. equiv. of each 66. 48.	Composition. $C^4H^2O^5$
Cyanic acid Fulminic acid	chem. eq. 34. 39.	Composition. $Cy+O$
Malic acid Citric acid	chem. eq. 58. 48.	Composition. $C^4H^2O^4$

* ισος, equal, and μερος, part.

In each of these instances, we have two acids composed of exactly the same substances, and in the same ratio, and of the same equivalents, yet possessed of very different properties. Another example may be cited in urea and the hydrated cyanate of ammonia, which are composed of:—

Urea.		
Carbon	12.24	2 eq.
Nitrogen	28.3	2 eq.
Hydrogen	4.	4 eq.
Oxygen	16.	2 eq.
	60.54	

Hydrated Cyanate of Ammonia.			
Cyanic acid	34.39	1 eq.	$(N+2C)+O$
Ammonia	17.15	1 eq.	$3H+N$
Water	9.	1 eq.	$H+O$
	60.54		

Therefore, "the neutral hydrated cyanate of ammonia has exactly the same ingredients and the same equivalent as urea; and whenever the elements for producing the former come into contact, they invariably constitute the latter. This production of urea ensues so rapidly, that mere exposure of the dry dicyanate to the air, or the spontaneous evaporation of its aqueous solution, suffices for the change. These phenomena illustrate in a most instructive manner, the subject of isomerism, and prove how possible it may be, by a difference in arrangement, to produce two different compounds with the same materials."*

The explanation of these facts must evidently be looked for in a difference of arrangement among the component particles. "Unexpectedly," says Dr. Turner, "as was the discovery of isomerism, it is quite consistent with our theories of chemical union; insomuch as the same elements may be grouped or confined in different ways, and thereby give rise to compounds essentially distinct. Thus the elements of sulphate of potassa may perhaps be united indiscriminately with each other, as expressed by the formula KSO^4; or they may form $KO+SO^3$; or $KS+O^4$; or KO^2+SO^2; and other combinations might be made. The second of these, is, doubtless, the real one; but no one can say that the others are impracticable."†

* Turner's Chemistry, fifth Amer. Ed. p. 271.

† Op. cit. p. 152.

Now I wish particularly to call the attention of the reader to the *nature* of these groups and combinations, and also to the general *causes* of their production.

First with regard to their nature. It is plain that if all the elementary substances in sulphate of potassa were united with equal forces (or *indiscriminately*, as Dr. Turner expresses it) we should have a compound expressed by the formula KSO^4. But such is not the composition of the salt;—it follows, therefore, of necessity, that in the formula $KO+SO^3$, the potassa and the acid are combined with forces of attraction very different from those which unite their elements;—that is, from those which unite the potassium and oxygen on the one hand, and the sulphur and oxygen on the other. In short, the degree of the force of attraction between the two binary compounds is different from that which unites their respective elements. So, it were possible to form the first above mentioned combination, could we get those elements to unite with equal forces and in the ratio prescribed; and the third and fourth, by first producing binary compounds and then placing them under circumstances in which they would unite according to the expression of the formulæ. In truth, as the attractions of aggregation and affinity run into each other by degrees, so are these degrees of force in chemical affinity; and this difference in force amongst the different particles, is what explains how the other formulæ might occur; and indeed all cases of isomerism.

This, perhaps, will be still clearer if we consider the constitution of some isomeric bodies, which, though composed of the same elements in the same ratio, yet differ as to their chemical equivalents. For example, three equivalents of *hydrous cyanic acid* by spontaneous decomposition yield one equivalent of *paracyanuric acid*, and that without the loss or gain of a single element. The following formulæ will explain this:—

Paracyanuric acid, 1 eq. 130.17.—$Cy^3O^6H^3$

$$\text{Hydrous cyanic acid}\begin{cases}\text{Cyanic acid} & 1\text{ eq.} \quad . \quad 34.39 \\ \text{Water} \quad . & 1\text{ eq.} \quad . \quad 9.\end{cases}\Bigg\} \text{—}(Cy+O)+(H+O)$$

$$43.39\times 3=130.17$$

Again, etherine and olefiant gas are composed of the same elements and in the same proportions, but have different equivalents.

Etherine	1 eq.	28.48.——	H^4C^4
Olefiant gas	1 eq.	14.24.——	H^2C^2—That is,

$$\left.\begin{array}{l}\text{400 cubic inches of vapour of Carbon and}\\ \text{400 " " " " Hydrogen gas}\end{array}\right\}\begin{array}{l}\text{are united and form 100 cubic}\\ \text{inches of Etherine;}\end{array}$$

Whilst,

$$\left.\begin{array}{l}\text{200 cubic inches of vapour of Carbon, and}\\ \text{200 " " " " Hydrogen gas}\end{array}\right\}\begin{array}{l}\text{united, form 100 cubic inches of}\\ \text{Olefiant gas.}\end{array}$$

In this last instance it is evident that the difference of chemical properties depends upon a *contraction* or clear approximation of the particles of carbon and hydrogen; and the same is probably the cause of the difference between hydrous cyanic acid and paracyanuric acid. I say *probably*, because there is another acid (the cyanuric) which is isomeric with the paracyanuric, having the same elements in the same ratio, and having also the same equivalent.

From all that has been said, it would appear that a mere diminution or increase of the force of attraction amongst the particles of a compound, will give rise to a change of properties; and farther, that there may be a great difference between the force which unites the elements of a binary compound, and that which unites that compound to another,—and so on, with all varieties of combination.

And furthermore, cases may occur where it is exceedingly difficult to say in what manner the elements of the compound are combined among themselves. The substance, called by Dumas *oxamide*, is an instance in point. This substance is formed during the decomposition of oxalate of ammonia by heat, and its elements are expressed as follows, $C^2+N+H^2+O^2$. It cannot, therefore, be an anhydrous oxalate of ammonia, since the crystals of the oxalate contain two equivalenst of water, and is, therefore, composed as follows:—

$$\left.\begin{array}{ll}\text{Oxalic acid} & C^2O^3\\ \text{Ammonia} & H^3N\\ \text{Water} & H^2O^2\end{array}\right\}=C^2+N+H^5+O^5$$

Now if we abstract the water, we shall have one equivalent of oxygen and another of hydrogen more than exists in oxamide; which must therefore be some other compound. It may be composed of:—

$(H^2+N)+2(C+O)$	.	Dinitruret of hydrogen, and carbonic oxide; or,
$(N+O^2)+(H^2+C^2)$	.	Binoxide of Nitrogen, and olefiant gas; or,
$(C^2+N)+2(H+O)$	.	Cyanogen and water.

Oxalic acid may furnish us with another example. This substance contains two equivalents of carbon and three of oxygen, and may, therefore, be regarded as a direct compound of carbon and oxygen; or as a compound of carbonic oxide $(C+O)$ and carbonic acid $(C+O^2.)$ "The latter," says Dr. Turner, "is supported by the fact observed by Döbereiner, that oxalic acid is converted into carbonic oxide and carbonic acid gases by the action of concentrated sulphuric acid."*

The question now comes up;—What *causes* this difference in the arrangement of the particles of a compound; and furthermore, why, when two isomeric bodies are placed under the same circumstances, is one not converted into the other?

Every particle of matter in the universe is possessed of activity; it is acted upon continually, and reacts in its turn incessantly upon surrounding bodies. Hence no substance whatever is completely isolated; and it likewise follows, that the condition, in which any body appears to us, is a *result* or *consequence* of these two things—the action of other bodies upon it, and its own reaction upon them.

When there is an equilibrium of forces the body will remain at rest without undergoing mutation of any kind. Therefore, to change the condition of a substance there must be some outward power applied, by which its relations with other bodies, or those of its own particles with respect to each other, are altered.

All cases of chemical action are the manifestations of superior forces overpowering inferior. For in whatever state we find a body, there must be some cause for its assumption of

* Op. cit. p. 499.

that state, for its retention thereof, and, if it undergo a change, for that mutation. Therefore, all changes in nature occur either from the removal of an existing cause, or the intervention of some superior force;—both amounting, in truth, to the same thing, namely, a change in the relations of a substance with other substances.

Bodies in their attraction towards each other undoubtedly evince a greater degree of it towards some individuals than towards others. This has given rise to the phrase *elective* affinity. Hence it is natural to infer that the order of decomposition is the measure of affinity. But we know that such is not the fact. For instance, if we mix together a solution of carbonate of ammonia and of hydrochlorate of lime, double decomposition will ensue;—carbonate of lime and hydrochlorate of ammonia will be formed. Now if the order of decomposition were the measure of affinity, it is obvious, that carbonate of lime should never decompose hydrochlorate of ammonia; yet if they be mixed together in a dry state and exposed to heat, double decomposition does ensue.

There are, therefore, other causes to be taken into consideration; disturbing or modifying forces, which interfere with the affinities of bodies for each other. The principal of these are *cohesion*, *elasticity*, *quantity of matter*, *gravity*, *atmospheric pressure*, and the agencies of light, heat, and electricity. Examples of the influence of each may be found in all systems of chemistry.

It is also manifest that in a case of decomposition, the force by which the separated particles cohere, must also be taken into account.

Therefore, according as the circumstances in which bodies combine or are decomposed, are more or less analogous;—according to the greater or less influence of these disturbing causes, may we naturally look for a similarity or difference in the results.

To make this obvious, let us attend for a moment to the formation of some substance isomeric with some other. Let us take olefiant gas.

Opening Dr. Turner's work, we find that olefiant gas is prepared by mixing in a capacious retort six measures of strong alcohol, with twelve of concentrated sulphuric acid, and heating the mixture, as soon as it is made by means of an argand lamp. The acid soon acts upon the alcohol, effervescence ensues, and olefiant gas passes over. The chemical changes which take place are of a complicated nature, and the products numerous. At the commencement of the process, the olefiant gas is mixed only with a little ether, but in a short time the solution becomes dark, the formation of ether declines, and the odour of sulphurous acid begins to be perceptible: towards the close of the operation, though olefiant gas is still the chief product, sulphurous acid is freely disengaged, some carbonic acid is formed, and charcoal in large quantities deposited.

"The olefiant gas in this process is derived solely from the alcohol; and its production is owing to the strong affinity of sulphuric acid for water. Alcohol is composed of carbon, hydrogen, and oxygen; and from the proportion of its elements it is inferred to be a compound of 14.24 parts or one equivalent of olefiant gas, united with 9 parts or one equivalent of water. It is only necessary, therefore, in order to obtain olefiant gas, to deprive alcohol of the water which is essential to its constitution; and this is effected by sulphuric acid."*†

* Op. cit. p. 247.

† If we mix *equal* parts of concentrated sulphuric acid and pure alcohol, ether will be produced instead of olefiant gas. This may be explained in two ways as follows:—

Alcohol.			*Ether.*		
Olefiant gas,	2 eq.	28.48	Olefiant gas,	2 eq.	28.48
Water,	2 eq.	18.	Water,	1 eq.	9.

If the sulphuric acid be in quantity sufficient to abstract the whole of the water, we shall have olefiant gas, as the product; if only sufficient to abstract half of the water, we shall have ether produced.

The other explanation presumes the equivalent of alcohol to be 46.48 instead of 23.24; therefore, both ether and alcohol may be considered as hydrates of etherine.

Etherine, the substance with which olefiant gas is isomeric, is prepared by a very different process;—as indeed are all bodies which are isomeric with each other.

It is, therefore, in these different *processes* that we are to look for the causes why bodies are obtained having the same elements in the same ratio and yet possessed of different properties. And what are these different processes? They, obviously, merely represent different circumstances in which the same elements are subjected to different disturbing or modifying forces.

With regard to the second part of this quere, we shall be brief. It may be put in this form;—why are not 200 volumes of olefiant gas converted into 100 of etherine; or 100 of etherine converted into 200 of olefiant gas, when both exist under similar circumstances?

The first question is, why does *either* retain its form? The answer is "by an equilibrium of forces;" that is, of affinity, cohesion, gravity, elasticity, etc., etc. To destroy this equilibrium some foreign force must be applied. Therefore, if we could apply a force so as to bring the particles of carbon and hydrogen in olefiant gas, nearer to each other, they would unquestionably

	Alcohol.	
Etherine . .	$28.48—H^4C^4$. . . .	$28.48—H^4C^4$
Water . .	$18. —2(H+O$ . .	$9. —H+O$
	$46.48=H^4C^4+2(H+O)$	$37.48=H^4C^4+(H+O)$

Berzelius on the other hand regards ether as the oxide of a compound inflammable body called *ethule* or *ethyle* (from ether and υλη principle.) On this supposition ethule consists of H^5C^4, so that the formula of ether is H^5C^4+O, a constitution analogous to that of camphor.

Another theory of the formation of ether, supposes, first, the formation of sulphovinic acid (or bisulphate of alcohol;) and secondly, the resolution of that acid into hydrated sulphuric acid and ether.

Mitscherlich, again, seems to have shown that sulphuric acid in certain cases acts simply as a catalytic force in the production of ether. When diluted so as to boil at 284° F., it decomposes alcohol into ether and water. Both these substances distil over, and together just equal in amount the quantity of alcohol originally employed.

be resolved into etherine. On the other hand, etherine would be converted into olefiant gas were it possible for us to separate the particles of carbon and hydrogen far enough apart.

Change of circumstance, however, is continually occurring, as in temperature, in light and darkness, in atmospheric pressure, in moisture and dryness, etc. These are of themselves frequently sufficient to convert a substance into its isomeric; or by an interchange of elements, into different compounds. Thus a slight increase of heat is sufficient to convert *hydrous cyanic acid* into *paracyanuric acid;* and the mere exposure of the dry *dicyanate of ammonia* to the air is sufficient to convert it into *urea.* So also pure *hydrocyanic acid,* and also *fulminic acid,* in a few hours undergo decomposition; and the mere addition of water converts *cyanic* acid into carbonic acid and ammonia. Numerous other examples might be cited.

Thus all the difficulties connected with this subject may be solved on the principle, that the only difference between the attraction of aggregation among heterogeneous bodies, and chemical affinity, consists in a greater or less degree of attractive force between the particles, and that the properties of a compound result from the *conjoined* action of its elements upon other bodies.

Catalytic Action.

Connected with this subject, is, what has been termed by Berzelius, "catalytic action," from the Greek καταλυειν, to *dissolve, destroy, decompose.** It is intended to apply to the action of substances, which remaining unchanged themselves, yet produce by their mere presence, intestine action and various mutations among the substances they approach.

An instance of this sort of action occurs when a piece of clear platinum foil is immersed in a mixture of hydrogen and oxygen

* The term is not very happily chosen, since the very first instance we give, is one not of *decomposition*, but of *combination.*

gases. The metal becomes hot, an explosion ensues, the gases unite, and water is the product. Iridium and several other metals possess the same property. The phenomena are caused by the reciprocal attraction of the metal and gases for each other. They (the gases) are brought thereby into close approximation and consequently unite;—the metal undergoing no change except that of temperature.*

Another instance appears in the decomposition of deutoxide of hydrogen by various metals; such as platinum, gold, silver, etc., into water and oxygen gas. Persulphuret of hydrogen is likewise decomposed by the same agents, being resolved into sulphur and hydrosulphuric acid. So also according to M. Pelouze, in *Annales de Chimie*, with regard to the nitro-sulphate of ammonia. "Spongy platinum, oxide of silver, metallic silver, powdered charcoal, and oxide of manganese, produce this effect; the first two mentioned especially, act with extreme rapidity upon the nitro-sulphate of ammonia. This remarkable phenomena is due, as in the case of the binoxide of hydrogen, to an action of presence, and it never produces more than a mere conversion of the nitro-sulphate of ammonia, into protoxide of nitrogen and sulphate of ammonia. Oxide of silver is not reduced, for if it be washed after having caused it to decompose a large quantity of this salt, it afterwards dissolves in nitric acid, without the disengagement of red vapours."†

Many instances of the same kind have been revealed by the researches of modern chemists. Of these we can but name a few.

If platinum in very fine powder be moistened with alcohol

* This experiment was first performed with *spongy* platinum, and it was thence inferred that the phenomenon was owing to the condensing power of porous bodies. Later observations, however, have shown that porosity is not at all necessary, though it expedites the union of the gases.

† Quoted by Dr. Draper in a paper published in the XLV. number of the American Journal of the Medical Sciences. I will here remark that the reader may find other cases of catalytic action related by this author in the Journal above-mentioned. See Nos. XLI. and XLV.—the first for November, 1837, and the other, for November, 1838.

and water, these substances will be converted into acetic acid; —the metal remaining unaffected.

When ammonia is passed through porcelain or glass tubes heated to a certain temperature, the gas is resolved into hydrogen and nitrogen. But if the tube be of *iron*, it is found that a much less degree of heat is required. The mere presence of the iron, therefore, must contribute towards the decomposition.

When ether is set on fire, the products of the combustion are *water* and carbonic acid; but if a coil of platinum wire be heated red hot and held over the surface of the ether contained in an open vessel, the wire begins to glow, and so continues until all the ether is consumed. The product is found to be *acetic* acid, in combination with some unknown compound of hydrogen and carbon.

Yeast converts sugar and water into alcohol and carbonic acid, and that without undergoing any change itself. Nor has atmospheric air any share in the phenomenon;—the yeast must, therefore, act by its mere presence. The united weights of the alcohol and carbonic acid are precisely equal to that of the sugar which disappears in the process.

In many instances, the catalytic substance unites with some body which it has caused the formation of. Thus, *hydrochloric acid* converts a mixture of *hydrocyanic acid* and *water* into *formic acid* and *ammonia*, the last of which substances, it then combines with.

1 eq. hydrocy. acid and	3 eq. water	yield	1 eq. ammon. and	1 eq. formic acid
$H+(N+C^2)$	$3(H+O)$		H^3+N	$2(C+O)+(H+O.)$

Again, potassa will convert a mixture of oxamide and water into *oxalic acid* and *ammonia;* and, after the change is effected, will unite with the acid, forming the oxalate of potassa.

1 eq. oxamide and	1 eq. water	yield	1 eq. oxalic acid and	1 eq. ammonia
$C^2+N+H^2+O^2.$	$H+O.$		C^2+O^3	$H^3+N.$

It is easily seen from the formulæ, that in both instances, there has merely occurred an interchange of elements, caused

by the mere presence of another substance, without the addition or abstraction of a single particle of matter.

We have remarked already that concentrated sulphuric acid converts oxalic acid into carbonic oxide and carbonic acid; therefore, if, in the last example, we use sulphuric acid instead of potassa, the oxamide and water will be converted into carbonic oxide ($C+O$) and carbonic acid ($C+O^2$) and ammonia; which last the sulphuric acid will combine with.

It must not be thought that in any of these instances of catalytic action, the axiom, "that action and reaction are equal," does not hold good. Both action and reaction do occur, and are equal to each other; but the reaction is not of sufficient power to effect a change in the catalytic substance.

It has long been known that the minutest quantity of antimony or lead was sufficient to destroy the ductility of gold. Even the fumes of antimony when in the neighbourhood of melting gold were found sufficient to take away its ductility; but until the experiments of Sir John Herschell, who proved that portions of sodium or potassium, in the proportion of less than a millionth part, could entirely reverse the electrical relations of mercury and impart to it sensible mechanical motions and properties of a definite character, but little attention was given to the influence of minute portions of matter. Many substances found in organic bodies in minute quantities were once considered as merely accidental, and no farther thought given them. Later researches, however, have shown that they merit a high degree of consideration. In fact, matter is a principle of activity, and wherever found, and in whatever quantity, must exert its influence; whether it exist in a state of mixture with other bodies, or in solution, (which differs from a mixture chiefly in a more uniform diffusion of the substances mingled together,) or in chemical combination. In all the mutations which the substances around it undergo, its influence will be felt; either by exerting a catalytic force upon them, or by entering itself into chemical combinations.

It is said, that chemical affinity acts only at insensible dis-

tances. This is true; for two substances could not act *conjointly* upon a third unless they existed in the closest approximation. But we may see from many facts, that both chemical affinity and aggregation are but mere modes of the same phenomenon;—in other words, they are but different manifestations of that general law of nature, *that bodies reciprocally attract each other.* Take, for example, the ascent of oil in the wick of a burning lamp. The oil is attracted by the wick and ascends; but when it has reached the summit, it there undergoes a chemical change, during which light and heat are given out, and gaseous compounds formed, which of course fly off. Now the combustion acts here just in the same way as if we removed the oil by mechanical means;—as the particles are removed, others flow to the spot through the attraction exerted on them by the wick. But the particles of the oil have also an attraction for each other; hence, a continued movement is kept up throughout a long succession of particles; and the oil will, therefore, continue to ascend until the supply is exhausted or the combustion arrested.

Another example occurs in living beings: the nutritive fluid is absorbed from the capillaries by the tissues, and whilst permeating their intermolecular spaces, undergoes a chemical change by reaction with the solid molecules. In this instance, a portion of the fluid remains fixed in the tissues, and goes to make up a part of them; whilst the residuary portion appears outwardly in the two forms of venous blood and the different secretions. As in the former instance, this series of phenomena will go on until the supply of fluid is exhausted or the chemical action arrested; of which contingencies as they actually occur, I shall speak hereafter.

It is important to observe, that in these cases, the absorption of the liquid by the solid body, will be proportioned to the intensity of the chemical action. For it is plain, that the velocity with which the liquid flows to the spot wherein the chemical change occurs, will be in exact ratio with the rapidity with which it is removed; and as it is removed only after it has

changed its chemical constitution, it is clear, that the absorption must be proportional to the action by which that change is effected.

I have dwelt somewhat long on these subjects, because I think them of the highest importance towards the elucidation of physiological phenomena.

CHAPTER IV.

ON THE MANNER IN WHICH THE CHANGE IS TRANSMITTED.

It has been shown in the foregoing chapter, that there exist many substances in nature which change their chemical relations with all other substances, when the relations of their component molecules to each other are altered. It follows, therefore, that in all highly compound bodies, the elements in the primary compound have certain dispositions with regard to each other; so have the primary compounds to each other; so also, the secondary, ternary, etc.

Now the agents, which may cause a change of relation in the molecules of a compound to each other, are plainly of two kinds;—the presence of some foreign chemical substance; and the contact of bodies producing molecular motion,—in other words, pressure. For that pressure by removing some particles farther apart, and bringing others closer together, might derange the relation of different molecules to each other, is so self-evident a proposition, that it need not be insisted on. The influence of pressure upon chemical actions must be familiar to every tyro in the science.*

It will also be observed, that the more highly compound a body is, the more liable it will be to suffer this derangement;

* "Numerous facts show that motion alone exercises a considerable influence on chemical forces."—*Liebig*, *Organic Chemistry*, p. 226, et seq.

for as all the molecules react on each other, their affinities will be more delicately balanced than in less compound substances, and therefore, more easily disturbed by extraneous influences.

Now of all substances in nature, perhaps the nervous is the most highly compound. The only analysis of the brain of man, which we possess, is that made by Vauquelin; according to whom, it is composed of water, white fatty matter, red fatty matter, albumen, osmazome, phosphorus, sulphur, muriate of soda, phosphate of potassa, lime and magnesia. We are very far from thinking that this analysis is really a representation of the composition of the nervous matter as existing in nature; but it answers the purpose in view, since all I wish to show, is its highly complex constitution. Leaving out primary, secondary, and ternary compounds, let us enumerate the chemical elements; and we have,—oxygen, hydrogen, carbon, nitrogen, chlorine, sulphur, phosphorus, sodium, potassium, calcium, and magnesium;—in all, eleven.

But we have another point to consider. If the compound be a hard solid, it is evident, that any derangement of its molecules will be resisted by the attraction of cohesion. And if a fluid, the particles left free to move, will, under the guidance of internal and external influences, settle down at last in the most permanent form; and, moreover, the elasticity of fluids, as well as the facility with which their particles roll over each other, and thus escape from under pressure, would oppose, if not confined, all mechanical agents in an attempt to affect their chemical constitution. It may be here objected, that a fluid is of all bodies, that in which we can most easily change the respective relations of its particles. But it must be kept in mind, that solution is not combination,—that chemical union is not the mere juxtaposition of particles, but *juxta-position under certain conditions*. We may derange, it is true, the relative positions of a fluid, as for instance, by shaking it up in a phial; but by so doing, we do not alter any one of the essential circumstances. In a solution of salt and water, we may remove a particle of salt from a particle of water, and put another particle of salt in its place; but it is evident that all the circumstances essential to the solution

have remained unaltered. It is not mere change of position, therefore, but change of relation in the elementary molecules, or in the primary, secondary, or ternary compounds, with regard to each other, that affects the chemical constitution of compound bodies. The manner in which a substance is converted into another substance isomeric with it, consists in the divorcing of particles already united, and forcing them into such approximation with others, that they conjoin and act with united affinities upon other substances.

A substance, therefore, existing in a medium state between solidity and fluidity; possessing little elasticity, but some tenacity; and so soft as to permit slight pressure to derange the relative positions of its molecules; seems of all others that fittest to undergo change in its chemical constitution by mechanical means; —and that the nervous substance possesses all these requisites, we need scarcely mention.

Another circumstance must be taken notice of. Bodies will be more liable to change their state in proportion to the activity of external influences. All bodies, to be sure, are subjected to the operation of exterior forces, for there is no substance in nature isolated: all is acted upon and reacts in turn, and continually. But these exterior forces are more numerous in some cases than in others and proportionally will be the liability to internal change. Now the nervous substance is perpetually undergoing change;—not only from the action of exterior agents, but from that of nutrition. In common with all the living solids it is bathed in the nutritive fluid, and a never-ceasing chemical action of production and destruction, of composition and decomposition, is going on among all its molecules.

And here another objection may arise. All the animal tissues are highly compound bodies; many of them are semi-solids; and all of them in the living state carry on continual chemical actions with the nutritive fluid; they, therefore, seem just as well adapted as the nervous substance, to take on isomeric changes; for we see no condition specified in the one case, which does not equally exist in the other.

The truth is, we do not think the nervous substance the only

one capable of undergoing change in its chemical constitution from the operation of mechanical agents; but being more highly *organized*, more *compound*, and therefore, with the affinities of its elements more delicately balanced than any other known substance, it possesses this property in a much higher degree. All organic matter, fulfilling the above specified conditions ought to possess it, if there be any force in the arguments used. And is it not so? Do we not observe the same property surging here and there on the ocean of vegetable life? Is it not evidenced in the *mimosa pudica*, *dionæa muscipula*, and other plants? Have we not proof thereof, in the fact, that in some delicate plants, death is produced by electric shocks so feeble as to cause no sensible impairment of structure?

In the polypi and medusæ, and indeed in all the lower orders of the radiata, we see but a homogeneous jelly-like mass, performing the function of locomotion, and possessing an imperfect sensibility. Chemically analyzed, this substance is not far removed from the nervous; but as we ascend in the scale of being,—as animals appear furnished with a more complicated organization, we see small threads of a distinct substance isolating themselves from the common mass. A little higher in the scale, we find these threads proceeding to certain central bodies, called *ganglia*, and meeting there with other threads coming from other parts. Here, then, is the first appearance of the nervous system;—but does the animal in which it appears in this rudimental state, offer no striking differences with respect to those lower in the scale? Yes, some important ones. The animal is no longer a homogeneous mass, but is composed of separate tissues, which combine together and form organs. These tissues are not only chemically different from each other, but also from the homogeneous matter of the lower animals. They possess a far greater proportion of earthy and saline substances; their consistence is firmer; in short, they begin to depart from the conditions necessary to undergo isomeric changes through the influence of mechanical agents. Another circumstance is, that the faculty of sensibility is no longer possessed by the tissues,

but is seated in the ganglia; and the sensibility is much more exalted and diversified, for here begin the special senses.

Let us consider also the manner in which the nerves terminate in the tissues. They are described as terminating in three different ways. 1. In regular anastomosing loops. 2. In a net-work. 3. In an isolated manner without being connected together. Schwann, however, is said to have seen numerous finer filaments given off from the so called primitive fibres, and that these filaments, here and there, presented small ganglia from which again smaller twigs were given off.*

Oken considers the gelatin of polypi, medusæ, etc., as the nervous substance in its lowest degree, and from which, other substances mixed up with it, or interfused in its substance, have not yet isolated themselves.†

De Blainville's remarks are peculiarly interesting. "Regard," says he, "the nervous and the muscular tissues. They do not exist, or at least, appear not to exist in the lower orders of living beings. Higher in the scale they make their appearance, but are still very different from what we see them in the superior animals; yet the animal perceives the external world, and contracts, while as yet we can discover neither nervous filaments nor contractile fibres. It is because both tissues being but manifestations of the general element of all organization, and not organs absolutely different from it, they appear with special and distinct characters only when this element or substance can no longer suffice for the more numerous and diversified relations, which animals are to maintain with the exterior world."‡

We are, in fact, altogether ignorant of the manner in which the nervous substance is connected with the different tissues; but facts show us that the union is most intimate, for impressions on the nerves may affect every corpuscle of the tissues, as is evidenced in local injuries modifying nutrition, secretion, and absorption throughout the entire system. We may, there-

* Müller's Physiology, translated by Baly, vol. i. p. 603.

† Carus, Anatomie Comparée, Tome i. p. 35.

‡ Carus, Physiologie, Tome i. p. 115.

fore, regard the nervous matter as molecularly mingled with the other solids—interfused, as it were, into their very substance—the two coexisting like zinc and copper in a piece of brass; or, we may regard it as but one of the forms or modifications of the original element (albumen) of all the tissues, and by gradual transformations becoming a part of the tissues to which the nerve is distributed. In this latter case, the primary change would occur among the molecules of the tissues, and be thence transmitted to those of the nerve.

From these and other considerations, we infer:

That the nervous substance is nothing more than the primitive organic matter (albumen) in chemical union with other substances; but from the peculiar nature of this union, and from the physical characters of nervous matter, it is far more susceptible of undergoing change than any other of the tissues.

That this susceptibility of change is diminished in the other tissues in proportion as they are removed from the conditions already specified; but they never lose it entirely, for all the tissues of the higher animals seem to be endowed with it. Hence, all the tissues are not equal in this respect; the fibrous, cartilaginous, and osseous, being far less *irritable** (to use the language of the schools) than the serous, mucous, or cellular. The same thing is observed in vegetable life, for among the sensitive plants, the degrees of irritability differ greatly.

That the deposition of nervous matter where we find it, is owing to the same circumstances and laws which conduce to the formation of the separate tissues, organs, and general forms.

That the existence of the nervous system gives rise to all those phenomena which are classed under the term of sympathetic affections. For with regard to most of the other tissues,

* L'irritabilité des parties souples, quoique dans différens degrés, selon leur nature, étant le propre de tous les animaux, et non une faculté particulière, n'est point le produit d'aucun système d'organes particulier dans ces parties; mais elle est celui de l'état chimique des substances de ces êtres, joint à l'ordre de choses qui existe dans le corps animal pour qu'il puisse vivre.—*Lamarck. Système Anal. des Connaissances de l'homme*, p. 140.

the change is too limited, too difficult to produce, and too slowly propagated, to suffice for the production of the phenomena which result from the existence of a nervous system. These remarks may receive illustration from the following account of irritability, as it exists in the sensitive plants;—plants, whose tissues possess this property in a much higher degree than most others, but still in a very inferior degree when contrasted with the animal tissues. "In all these plants (which, taken collectively, we may call *sensitive*) a slight shock causes, more or less rapidly, the closing together of the pair of follicles which receive the impression; a stronger shock causes the closing of all the follicles of the branch; one still stronger, the closing of the follicles of the neighbouring branches, and a drooping of the branches themselves; the common petiole falls under a shock still more intense; and finally, if the commotion extend to the trunk, the whole of the leaves of the plant present the same phenomenon."*

Let us now take up the second part of the problem, which is, to account for the rapid transmission of the nervous change to distant parts. This, it must be confessed, is the serious difficulty; we are apt to think that the transmission would take place slowly; that it must require some appreciable portion of time to affect molecule after molecule along the course of the nerve. The rapidity of the transmission is what surprises us; for there is no great difficulty in conceiving the rest of the phenomenon. Yet we think this difficulty more apparent than real; or, at least, that we shall find it on examination not more insurmountable than other phenomena in nature, which are supposed to be well understood.

As the first change in the chemical constitution of the nervous substance is caused by external agents producing motion among its molecules, it is clear, that if we can show how molecular motion is transmitted along the nerve, we shall account for the transmission of the chemical change.

Motion is communicated to bodies in two ways: by impulse

* De Candolle, Physiologie Vegetale. Tome ii.

and by attraction; when a piece of metal, stone, or wood, of whatever length, is struck at one end with a hammer, a vibratory motion is instantly perceived by the hand of a person, placed at the other extremity. In this case the motion communicated is by impulse, and it is simultaneous throughout the mass, between the fall of the hammer and the sensation experienced, there is no appreciable portion of time, at least to our imperfect senses. And yet our reason tells us;—and we cannot but believe that this motion has been propagated from molecule to molecule along the entire mass. But the movement produced is *oscillatory;* the cause of which species of motion is the attraction of cohesion which tends to keep the molecules together, and therefore reacts, in the present case, to bring them back into their former relative position.

Now we might rest the argument here; for if cohesive attraction can thus operate on molecule after molecule, and in such minute portions of time that the whole amount is inappreciable; so, likewise, may chemical affinity be conceived to do the same in a substance constituted of such delicate affinities, that mere change of place among its molecules is capable of changing its chemical constitution. In both instances, it is *attraction* operating, and there is no more difficulty in the one case than in the other, for cohesion and chemical affinity are but different expressions of a general law of nature, viz., that bodies have a tendency to approach each other:—they are but different manifestations of the same principle.

But it is not necessary that we should here rest the argument, since we have, in many natural phenomena, examples of attraction producing molecular motions propagated in indivisible instants of time throughout large masses of matter; (an obvious instance occurs in capillary attraction.) Is the effect in this phenomenon limited to the approach of the adjacent liquid particles to the sides of the tube? Certainly not:—there is an instantaneous rise of fluid in the tube; a simultaneous movement in a long series of liquid particles. Other examples may be found in all cases of the absorption of fluids by solid bodies; but perhaps the most striking instance is to be met with in the

influence of the moon on the waters of the ocean. The attraction of this satellite operates at first on those particles of water which are exposed on the surface of the sea. But these particles cannot obey the attractive force without drawing others after them, and these last must draw others; so that an almost instantaneous effect is produced upon myriads and myriads of particles in succession. Yet all these are but instances of attraction operating without chemical change ensuing. When that occurs, the intestine movements must be far more rapid and violent; and should, therefore, be propagated more quickly.

We see, then, that the propagation of motion by attraction is equally rapid as that by impulse. In both cases the motion is transmitted from molecule to molecule, and no difficulty encumbers our conceptions in the one case, that does not equally encumber them in the other.

So then if an impression be made on the surface of the body, it will by causing motion among the molecules of the nervous substance affect its chemical constitution. The effect at first is local; but as all chemical change is attended by intestine molecular motion, the local change must necessarily bring on a change in that continuous line of particles which constitute the nerve. Hence the local affection is transmitted unchanged along the nerve, provided it be in no part diseased.

The chemical changes produced in the constitution of the nervous matter may vary in kind, in intensity, and in duration. Of the different species of these changes we shall have much to say hereafter; but it may be here remarked that the duration and intensity are generally in direct ratio to each other. The change may be so slight that upon removal of the disturbing cause, the nervous matter is almost immediately restored to its former condition. This is observable in our ordinary muscular movements, and in our common sensations: they disappear almost instantaneously with the causes which called them into existence. At other times, the change is more permanent and does not pass away even for many days. The sensation produced by the mere contact of my hand on another part of my body ceases almost instantly;—the pain occasioned by the prick of a

pin, lasts longer; that of a lacerated wound longer still; and so on. Similar remarks might be applied to the effects produced by nervous transmissions with regard to the functions of nutrition and secretion.

But if the nervous matter is thus altered what brings it back to its original state? The very laws and circumstances which in the first place conduced to its formation; the chief of which is nutritive action. Though the nervous substance has undergone an isomeric change, the reciprocal operations of its own particles and those of the nutritive fluid do not cease even for an instant. This is proved by the fact that if we arrest the arterial current going to the brain or spinal marrow we immediately annihilate their functions. Hence within certain limits, the constitution of the nervous substance will be restored;—out of those limits, death is the consequence. We see this exemplified in sudden deaths from lightning, blows on the stomach, and prussic acid:—the change is so great, so thorough that the relations between the nutritive fluid and the tissues—those relations which are a *sine qua non* to the production of vital phenomena—are broken up, and another train of chemical actions ensues, the result of which is death and finally decomposition.

Indeed if we attend to what passes within us we shall in many cases be able to observe, as it were the gradual return of the nervous substance to its original condition. If a billiard ball, for instance, be placed in contact with the skin, we shall at first experience certain sensations; but if it be kept there, provided no pressure nor motion be made, we shall gradually lose the consciousness of its presence. In some cases too, it can be proved that a succession of changes in the nervous substance is requisite to the production of sensation. The sense of hearing, for example, is affected, not by one impulse from the atmosphere, but by a series of pulses in quick succession;—in other words vibratory motion of a certain intensity is required to produce sound. But if a series of pulses be necessary, it is plain that a series of changes must occur in the nerve of hearing, otherwise, the first appulse would be sufficient. "The particles of air must in their *first* appulse then, produce a certain state or

change in the nervous matter; in their *second* appulse a different state by acting on an organ already affected in a certain manner; in their *third* appulse a still different state, and thus successively, till, *at last* they produce that particular definite state of the sensorial organ, in consequence of which, the *mind* becomes instantly *sentient*,—a state which could not have been produced by any single appulse of the particles on the unaffected organ, because the vibration, or a series of pulses, would not have been necessary."* Now if the nervous matter thus goes through a series of changes previous to the production of the sensation, it is evident, that it must pass back through the same to reach its original condition.

But perhaps a better illustration of this subject will be found in the organ of vision. If we regard a bright object for some moments and then close the eyes, we shall observe a spectrum of the object but of a different colour, which will gradually pass into some other colour; and that into another, and so on;—each spectrum being more faint and indistinct, until the nervous matter is restored to its former state, when the phenomena cease altogether.

So far we have been speaking of *isomeric* changes in the nervous substance, that is, mere changes in its chemical constitution without loss or gain of foreign matter. But these isomeric changes which are so often repeated in the daily avocations of life, must have certain consequences, which may be deduced from the principles, and are known to occur in reality. These consequences are a series of chemical changes not merely in the constitution but in the *composition* of the nervous substance. There must then of necessity be some limits to the continuance of nervous actions; and there must also exist some means whereby the nervous substance may be reinstated in its former condition; for otherwise disorganization and death would be the consequence. The remedy alluded to, is *sleep;* during which, the mind is not exerted; the muscles are no longer called into action; and the senses are withdrawn from stimuli; during the repose

* Brown's Philosophy of the human mind, lect. xxi.

of the animal powers, nutritive action however goes on; the arterial blood is sent into the tissues, and the nervous substance is restored to its original condition.

The state of the nervous system which precedes sleep is called *exhaustion*, and is produced in this way. When an isomeric change occurs in the nervous substance, its relations with the nutritive fluid are, of course altered; its nutrition will consequently be affected, that is, its chemical composition will undergo some modification. This is a necessary consequence from the principles of chemistry; and it is no slight conformation of the present theory, to find how well it tallies with the well known fact that sleep is sooner or later induced in proportion to the exercise which the mind, senses, or muscles have undergone.

CHAPTER V.

ON INNERVATION.

To sum up: 1st. We know from actual observation, that two bodies, which possess altogether different properties, may yet at the same time be composed not only of the same elements, but of those elements in the same proportions.

2d. Whatever be the ultimate cause of these facts, we must admit, that an entire change in the chemical properties of a substance may occur without the addition of foreign substances, or the abstraction of any of its component molecules. We can conceive this to occur in no other way, than by different arrangements of its particles.

3d. It is not contrary to strict induction, therefore, to admit the existence of substances whose intermolecular affinities are so delicately balanced, that mere molecular motion may disturb and disarrange those affinities; the result of which will be that the particles will enter into new combinations,—in short, that an isomeric body will be produced.

4th. Of all substances, the nervous matter, from its chemical constitution and physical condition, seems best adapted to undergo such a change.

5th. We can, therefore, understand how mere impulsion acting on a few molecules of nervous substance can affect its chemical constitution; for the movement communicated to those

particles, produces a change in their relations to other molecules, and consequently a new order of affinities comes into play in this highly compound substance: it will be made isomeric with what it was the moment previous.

6th. The change having once occurred, will be propagated along the nerves; for their particles are all continuous, and are subjected in succession to the same disturbing causes.

7th. The result of these isomeric changes must from the laws of chemistry, be a change in the chemical constitution of the nervous substance; for they are perpetually interfering with the actions of nutrition.

This interference in the condition of other parts through the intervention of the nervous system is called Innervation—a word whose meaning requires to be settled, for it is continually employed very vaguely and very indefinitely.

From the theory which prevails in the schools and which teaches that a material substance flows from the brain (the secernent organ) to the tissues and organs of the body, has arisen the phrases "want of Innervation," "loss of Innervation," etc. For example, if one of the larger nerves of the extremities be severed by the blow of a dagger or in any other way, the limb will in a short time lose its natural heat and become exceedingly pale, accordingly it will be said that the phenomenon is owing to a loss of innervation. But this way of talking is a very loose one, for in a few hours a condition exactly opposite will come on,—the limb will grow hot and red, in short, inflamed. Is this too owing to a "*loss of Innervation?*"

According to our mode of viewing the subject, the nervous substance is altered chemically at the point where the nerve is divided, this change is propagated down the nerve into the tissues, causing a chemical change in them and of course placing them in a different relation with regard to the arterial blood. Hence the results. The mode in which the after-change takes place, or the transformation of the cold into the hot stage will be spoken of hereafter.

In the same way do we read the experiments of Brodie and Chossal, in which, the elimination of animal heat was arrested

by dividing the spinal marrow and medulla oblongata; also, those of Legallois, W. Philip, Brachet, and others, in which the circulation in the capillaries, the motion of the heart, etc., were impaired or totally arrested by wounds made on the nervous system.

A change then is transmitted along the nerves to the tissues and their condition is affected; and this change in their condition and the effects produced by it, we refer to when we speak of Innervation. As already mentioned, it includes five classes of phenomena—*change of nutritive action*, *muscular motion*, *sensation*, the *intellectual affections*, and the *emotions;* but as the change is essentially chemical it is obvious, that in each of the latter, the first is included. If the muscle, sensorium, or brain is altered in its condition, it must also be changed in its relations with the nutritive fluid. Muscular contraction, sensation, thought, etc., are, therefore, merely results peculiar to certain organs and concomitant with change of nutritive action.

Innervation, then, includes all those phenomena which result from a change in the chemical constitution of the tissues, caused by the transmission of nervous affections; but as the world has made a distinction between health and disease, terms have been introduced to keep it up in this quarter: *innervation* being employed to denote the phenomena of health; and *lesion of innervation*, those of disease. But there must always be some difficulty in the application of these words, for the phenomena of health and disease run into each other like the colours of the rainbow. Pathology begins and frequently ends in physiology; we see a marked difference on the extremes, but there is a middle point where they blend, and to fix exactly where the one ends and the other begins is impossible. Who shall tell us the precise point where an *excitant* becomes an *irritant*.

It has been already observed that the great, the essential phenomena of life, are *absorption*, *nutrition* and *secretion;*—phenomena which depend on the organization of the tissues, and on their chemical constitution together with that of the nutritive fluid, they being reciprocally adapted to each other. Any change, therefore, in the constitution of the tissues must neces-

sarily produce some variation in these phenomena; and we shall find such to be the case.

In vegetables the essential processes of life are carried on by the reciprocal actions of the tissues and the nutritive fluid. The sap, after having undergone the action of the atmosphere in the leaves (or otherwise) comes in contact with the innumerable small vesicles, that make up the plant, is absorbed by the areolar membrane of which they are composed; is changed in its condition during the passage; and thus altered, enters and fills the vesicles, when, from its more fluid parts being absorbed, or from reaction on itself, it undergoes still farther changes. This series of actions in constant operation, constitutes vegetable life.

Exterior physical agents, such as caloric, light, wind, water, etc., undoubtedly exert their powers and modify according to circumstances the nutritive actions of vegetables; but the effects are confined for the most part to those portions of the plant, on which the agent immediately acts. If, like caloric, the agent be general, the effect must be general;—nutritive action will be modified throughout the entire plant whenever its temperature is increased or diminished. But when the external agent is partial in its action, the effects are chiefly limited to the parts implicated. A general affection from a local application can only occur in one way, and that is by transferrence in the nutritive fluid. Hence it is we may make serious irruptions on the organization of a plant, and yet leave the parts which are untouched, in a fresh and vigorous condition. We may kill a plant by suffering its roots to absorb sulphate of copper; for the poison is carried by the ascending sap every where into the parenchyma; but we may hew or saw off immense limbs from a tree without doing injury to the rest of it.

In an animal, external influences also modify nutritive action; but beyond this, the two kingdoms present striking differences, which result from the existence of a nervous system. The influence of physical agents upon animals is *not* limited to the parts on which they act. By the nervous system, the actions of every part of the body are catenated with those of all other

parts. The slightest touch on the surface is propagated to the brain and becomes a sensation, which in its turn may become the cause of other effects. This simple fact is proof that the animal is subjected to the influence of many agents which have no effect on the vegetable. Through the medium of the senses, causes even far distant, such as percussion in the atmosphere, the object of vision, etc., may exert an influence upon him. Indeed all bodies that surround him, from birth to death, are in perpetual operation upon him, causing at every instant some change or other in the nervous substance, and of course modifying in consequence the actions of life; nor is this all. These external agents acting on the nervous substance give rise to secondary effects, which, in animals provided with a brain, are manifested in the passions, instincts, and moral emotions. These in their turn, especially when occurring in the nervous substance of the highest point of organization, (that is in man) become causes far exceeding in the variety and importance of their effects all others combined. An external cause, trivial in itself, may become through the mental affections of momentous importance. A few lines scrawled with a pencil; what are they in themselves; that is, considered without reference to the living brain? almost nothing. Yet acting on that wonderful and mysterious pulp, they become the messengers of life or death—of overwhelming joy or measureless despair.

When the operation of physical agents is confined within certain limits, the animal is said to be in health; when these limits are passed, it is said to be in a state of disease. Nor should it excite surprise that the constant occurrence of these changes in the nervous substance does not so interfere with the actions of nutrition as to change them altogether and thus finally destroy life. It must be remembered that these *excitations* are a part and an essential part of those circumstances in which animal life is fitted to exist. It is by them that the nutritive actions are rendered peculiarly *animal;* and were it not for them, the animal could not exist as such. The actions of nutrition and these excitations are adapted to each other, they co-exist and are inseparable. Abstract from man or any other animal, as far as

possible, the presence of those physical agents (surrounded by which he is formed to live, and the influence of which he seeks by intuitive feelings) and in a short time, disease and death are the consequences. The nutritive actions without these stimulations run into *morbid* actions; so that it is plain nutrition in animals is not merely the result of reciprocal actions between the nutritive fluid and solid molecules only, but also, of constant changes occurring in the nervous substance from the influence of exterior agents. Give a vegetable a certain quantity of light and heat; keep up a supply of nutritive fluid; surround it with fresh air; and you have almost all the requisites of vegetable life. But something more is required for animal life—namely, nervous excitations, put in play by exterior agents. We have evidence of the truth of this in some facts which have been adduced in favour of the theory of a flux and reflux of nervous fluid to and from the brain. If a nerve be divided and does not re-unite, the muscles dwindle away in size, and after a time the nerve itself seems to undergo a change of structure, for it will no longer, though galvanized, excite the muscles to contraction.* No doubt there has occurred a change of structure in the nerve, but it has occurred from the causes mentioned above;—want of those excitations which are essential to its healthy nutrition.

Every part of a living being is in some degree dependent on every other part; nothing is isolated: all act upon and are re-acted on in turn. The condition of the brain or spinal cord affects all the other organs; the condition of these organs re-acts on the brain and on each other. In health this occurs as well as in disease. The loss of the testes prevents the development of the larynx, and the growth of beard; the malformation of the ovaries or uterus prevents the expansion of the mammæ, etc.† A certain condition of the stomach gives rise to certain affections of the brain, a certain condition of the testes, to other and very different affections.‡

* Müller's Physiology, Part iv. p. 898.

† Consult on this subject the writings of Cabanis and Broussais.

‡ Toutefois, il est des femmes chez lesquelles le clitoris acquiert un bien plus grand dévelopment. On l'a vu quelquefois parvenir jusqu'á la longueur d'un,

The molecular changes which occur in the nervous substance, are confessedly beyond the reach of observation, but as we see certain effects produced in the tissues by impressions made directly on the nervous substance, it is plain that these effects may be taken as the representatives of their immediate causes;—that is, of the changes undergone in the nervous matter; and this may be done with equal surety, whether the change in the actions of nutrition be brought about by primary lesions of the nervous substance; or by some morbific agent conveyed into the tissues by the nutritive fluid, or by external causes acting on the solids; or by the nutritive fluid itself, changed in chemical constitution, and thus become a morbific agent; for no change can occur in the tissues without affecting the nervous substance which is so intimately connected with them. So that whether the alteration of the nervous matter be primary or secondary is really here a question of no importance, since in either case, its real condition must be the same, when characterized by the same symptoms.

The effects produced by changes in the nervous substance, include of course every phenomenon that occurs in the animal tissues in health and disease, so that were we obliged to rest here, we should have gained but little, but if we can show that there are certain *primary* effects produced by nervous influence, to which the others are of necessity consequent or concomitant;—and if we can show that these primary effects are apparent in a vast number of phenomena, normal and abnormal; we at once strike upon distinctive differences, and take the ground of a natural classification.

deux, trois et même de cinq pouces. Alors, il diffère à peine de son analogue dans l'autre sexe.

Une pareille disposition est remarquable, en outre, en ce qu'elle coïncide avec certaines caractères qui ont pu porter à penser que les êtres ainsi conformés n'appartiennent pas plus à un sexe qu'à l'autre; c'est-à dise, que ces femmes ont en général peu de gorge, les traits durs, de la barbe, un caractère qui les porte à préférer les occupations etrangères à leur sexe. Elles sont grandes, et aiment à se procurer des jouissances illicites avec leurs semblables. En un mot, ce sont ces individus qui ont le plus souvent donné naissance aux questions relatives à l'hermaphrodisme.—*Velpeau, Traité des Accouchemens, p.* 77.

Of course these primary effects are better developed in disease than in health; but at the same time they are mixed up with a greater number of secondary phenomena. How shall we distinguish them?

"The existence of general derangement," says Andral, "is betrayed to us by symptoms which may be referred; 1. to an excitation of the vital force; 2. to its being lowered below the regular standard; 3. to its perversion. Hence the existence, in every disease of three fundamental dispositions which, whether preceding it or produced by it, impress on it in every instance a peculiar character direct its progress, produce its complications, determine its severity, and lastly, regulate the indications of treatment.

"These may be termed the *hyperdynamic* the *adynamic* and the *ataxic* disposition. Thus then, in every disease, to study the various circumstances external or internal, which with or without an accompanying lesion of organization determined of one or other of these three dispositions; to estimate the influence which these dispositions exert in their turn, over the organization; to distinguish the modifications of treatment they require; and to reduce to laws the result of these observations; such should be the aim of the physician."*

To illustrate these remarks, let us review the phenomena which characterize an acute disease in which the whole system is implicated. And in order to render the subject as little complicated as possible, let us take the case of an individual who, just before in perfect health, is now suffering from a violent injury done to a part not essentially vital. We will suppose his leg to be crushed by machinery. If we are called to this man immediately after the accident, we shall find him with an icy cold and clammy skin, with cold and bluish tongue, with pulse almost imperceptible, slow and intermittent; we shall also find his respiration slow and heavy, his senses impassive to impressions, proportionally to the severity of the injury and its effects on the brain; and perhaps we shall also witness the vomiting of a watery fluid, diarrhœa, and the emission of limpid urine.

* Anat. Pathol., Tom. i. p. 574.

Gradually and with intervening symptoms (which it is not important now to take notice of) the patient passes into a very different and even opposite condition. His pulse becomes bounding, quick and tense, his skin, hot and dry, and his tongue white and coated, with the papillæ erect, and red. His urine is high coloured and disposed to deposite a lateritious sediment; his sensations grow acute and altered, he suffers a burning thirst; he is restless and throws himself about in bed; in a word he is the victim of all the inflictions of a high fever. As these symptoms die away the patient passes into what may be called the third stage. The symptoms characterizing this condition are, great debility, great irregularity in the capillary circulation, parts becoming red and pale without obvious cause, and great derangement in the secretions. The extremities grow suddenly cold and immediately afterward become quite hot; the tongue is sometimes moist and sometimes dry; copious perspirations alternate with hot and dry skin, and abscesses frequently form suddenly and without much previous inflammation. We meet also with slight coughs from increase of the bronchial secretions, diarrhœa, alternating with constipation, hurried respiration after the slightest exertion, local inflammations leaving other organs in a state of anæmia, fœtid urine, etc., etc. The mind is also much affected in this stage;—it is easily discomposed by trivial causes; the patient flies into a fit of anger which his system is unable to support, he trembles, attempts in vain to articulate, and finally swoons, or is relieved by a burst of tears; a sudden noise or the appearance of any thing unexpected, causes terror and trembling; when the muscles are put in action they act apparently with hesitation—the limbs tremble, and with difficulty are the commands of the will obeyed. This state terminates by a gradual amelioration and return to health;—or in death.

Now we think these three conditions of the system thus marked out by nature, may be assumed as the true basis of a classification. Each of them is opposed to the others in character, and each requires different remedies,—what would be serviceable in one, would probably bring on death in the others. It is true that they run imperceptibly into each other; but it will

be found, that during the passage from one state to another the symptoms are of a mixed character and pertain to both. Nor does this circumstance militate in the least against the distinctiveness of each separate condition when fully formed, any more than it does against the distinction which all allow between health and disease.

But we see that each of these conditions is characterized by many phenomena. Now in all studies of nature, it is the part of the student to analyze the complex facts which appear before him to settle what is antecedent and what is consequent, to inform himself which of them bear the relation of cause and effect to each other, and thus mount from phenomenon to phenomenon until he can show that they all take their source from certain general principles. To do this, it certainly is the safest way, to observe the phenomena themselves; reflect what are the immediate causes that could have produced them; then what could have been the precursors of these causes; and so mount upwards to the original or first cause in the series. By so doing we never lose sight of those first and general principles in which natural philosophy culminates; and at the same time, we run less risk of framing gratuitous hypotheses.

The state of the present subject then is simply thus; we observe many and various phenomena produced in the tissues by impressions made directly on the nervous substance:—we are to take these phenomena and analyze them, and if we can, reduce them to primary facts and general principles. This problem we shall now attempt.

We shall assume as the basis of our classifications the three divisions pointed out above. But at the same time it must be distinctly kept in mind, that each of these divisions is a generalization itself, and comprehends under it many species which though bearing the general characteristics, yet are by no means identical: but more of this hereafter.

CHAPTER VI.

ON CERTAIN EFFECTS PRODUCED BY THE MUTUAL ACTION OF THE NUTRITIVE FLUIDS AND SOLIDS.

There are certain consequences resulting from the mutual action of the nutritive fluid and solids, which it will be necessary in this place to explain. To do so, I must assume certain principles, the truth of which I do not think will be questioned by any one conversant with the present state of physiology. For the sake of brevity, I shall propose them as aphorisms.

Aphorism I.

Every living being is composed of solid parts, and a fluid, called *nutritive;* and it is by their reciprocal action on each other that the phenomena of life are produced.

II.

The action spoken of, is essentially a *chemical* one, since it results in the transformation of substances into others chemically different. The results, reduced to their simplest expression, are *nutrition* and *secretion*.

III.

Like all other species of chemical action, that of nutrition will be more or less intense, according to the relation which the

nutritive fluid and tissues have to each other. That is to say, if either be altered in composition, nutritive action is perverted, and at the same time, according to circumstances, it may be increased or diminished in intensity.

IV.

When oxygen, carbon, and hydrogen are present, heat will be eliminated in proportion as nutritive action is more or less intense. Hence in animals that consume much oxygen, the heat of their bodies is increased by the exaltation, and lessened by the diminution of nutritive action. The oxygen is absorbed into the blood by the lungs: the carbon and hydrogen are *probably* furnished during the decomposition of the old solids.

V.

Nutritive action essentially consists in what is termed "Life." It is, therefore, common to vegetables and animals. *Vitality*, which expresses a mere condition—*the fitness of bodies to undergo this action, when certain circumstances are fulfilled*—must be distinguished from life. Thus, the ova of the plants and of many animals possess, at certain periods, *vitality*, but not *life*.*

VI.

Absorption, nutrition, and secretion, constitute the essential

* In the idea of life, *vitality* is of course included. But life expresses essentially a state of action; vitality may merely represent a state of repose. The latter is dependent on two things:—a certain chemical constitution of organic matter, and a certain arrangement of particles. If either be destroyed vitality is lost. Vitality being dependent on these conditions may exist for an indefinite period. Thus wheat, found wrapt up with Egyptian mummies, has been known to germinate and grow, as well as if it had been gathered the preceding harvest.

Life, on the contrary, runs from a certain beginning to a necessary termination. By the continued operation of the nutritive fluid on the solids, they are gradually altered, and at last lose their fitness to undergo those actions in which life essentially consists. Hence, to use the language of Cuvier, "death is a necessary consequence of life."

phenomena of *vegetable* life. The addition of sensation and volition constitute *animal* life.

VII.

Nutrition and secretion, being results of a chemical action, must take place *extra vasis.* The vessels are mere conductors of the nutritive fluid to the neighbourhood of the spot where it is required.

VIII.

Absorption of the nutritive fluid into the tissues must necessarily occur before nutritive action can take place. In the higher animals the materials required are absorbed by the solid molecules through the thin, delicate coats of the capillary vessels.

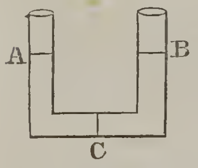
IX.

As the nutritive fluid, after being absorbed, undergoes a chemical action with the solids, it is obvious that it must penetrate them intermolecularly.

X.

Absorption results from the mutual attraction of the solids and fluids; and is a phenomenon perfectly analogous to the rise of liquids in capillary tubes; to the imbibition of water by dry wood; to the phenomena, termed *endosmose* and *exosmose* by Dutrochet;* to the solution of a salt in water, etc., etc.

* From ενδον, within; εξ, without; and ωσμος, impulsion.—The terms are not happily chosen. The manner of performing the experiments gave rise to them.



To make this clear, let us employ an instrument like that in the margin, the two limbs, A and B, being filled to equal heights with different liquids, and separated by a membrane, C. There will be accumulation in A, or B, according, not only to the substances employed, but also according to the kind of membrane made use of.

The theory of the matter is this. The membrane C absorbs that portion of the liquid in A in immediate contact with it;—this liquid comes in contact with that in B, and is immediately taken up by reciprocal attraction. The membrane also absorbs the liquid in B, which, after passing to the other surface, is taken up by that in A. This will go on until there is a

XI.

Bodies, in their attraction for each other, display different degrees of force. Thus mercury sinks in a glass capillary tube, whilst water rises;—water penetrates animal membranes much more rapidly than alcohol, whilst the reverse occurs if the membrane be of gum elastic;—alcohol mixes easily with water, but oil will not,—its particles having a greater attraction for each other than for those of water.

XII.

The rate at which a fluid is absorbed into a solid, will depend upon two things; first, the force of attraction which they have for each other; and secondly, the rapidity with which the absorbed fluid is removed from the solid.

This is so important a proposition that I call particular attention to it. It has already been illustrated by what occurs in a burning lamp.

In the lamp the oil is converted into gas and flies off. In living beings we must make a distinction between the absorption of the nutritive fluid and other substances. Fluids, other than the nutritive, (provided, they do not act chemically on the tissues and thus prevent the effect,) are taken at once into the capillary vessels, and are thus swept into the torrent of the circulation. The rapidity with which they are absorbed will,

thorough admixture of the two liquids; when gravity will again establish an equality in the height of the liquids in each limb.

Now it is evident that accumulation will occur in A or B in the inverse ratio of the force of attraction that exists between the membrane and the respective liquids. If the membrane absorb the liquid in A faster than that in B, accumulation will take place in B, and a fall of the liquid in A; and if the membrane absorb the two liquids at the same rate, there will be no change in the height of either fluid, though a thorough admixture of the two will take place.

The same series of phenomena occurs in respiration. The membrane lining the air vesicles absorbs oxygen from the atmosphere, this in its turn is absorbed by the blood, and whirled into the vortex of the circulation. On the other hand, the membrane takes from the blood carbonic acid gas, which is taken away in turn by the atmosphere contained in the lungs.

therefore, (all else being equal,) be in direct ratio with that of the circulation.

But as will be hereafter shown, nutritive action is one of the forces of the circulation, even in animals possessed of a heart; and it has been already mentioned that this action may be increased or diminished by a change in the chemical constitution of the tissues. Therefore, (to quote a passage from another part of this work) when liquid and solids act chemically on each other, the absorption of the liquid by the solid will be proportional to the intensity of the chemical action. For it is plain, that the velocity with which the liquid flows to the spot wherein the chemical change occurs, will be in exact ratio to the rapidity with which it is removed; and as it is removed only after it has changed its chemical constitution, it is clear that the absorption must be proportional to the action by which that change is effected.

XIII.

Exhalation must be distinguished from secretion. The former is the mere appearance outwardly of some portions of the nutritive fluid. It occurs from two causes—the attraction of matter in contact with the body, as atmospheric air, or other substances;—and, internal pressure, such as that exerted by the heart and arteries.

Secretion, on the other hand, is the product of a chemical change effected on the materials of the nutritive fluid.

From the above propositions we arrive at an easy solution of many interesting phenomena.

Ascension of Sap in Plants.—The liquid absorbed by the areolar tissue at the extremities of the roots, is water, generally containing saline substances in solution. It reaches the leaves, where it meets with carbonic acid gas absorbed from the atmosphere, and, by combination with the carbon thereof, forms *mucilage;*—the nutritive fluid of plants.

Vegetables have no organ analogous to the heart of animals, nor do their vessels contract so as to propel their contents onward. What, then, is the power that elevates the sap? Unquestionably, that of the nutritive process.

For the rapidity with which the sap ascends is in direct ratio to the intensity of the nutritive action.

Heat, it is well known, increases the intensity, or, if you please, the rapidity of all chemical actions. Cold, on the other hand, diminishes it. Observe, then, a tree in winter and at the commencement of spring. In winter it is leafless, apparently sapless, all life, as it were, suspended. The warmth of the spring comes on, and life arises, as it were, from the grave.

The *vitality* of the tree was preserved. In short, the presence of heat, has set in movement nutritive action throughout the plant. The water absorbed by the roots, is elevated into all parts, but especially into the buds left by processes undergone the preceding year. In its passage it meets with fecula preserved in the roots, bulbs, and other portions of the plant, converts it into sugar, and a nutritive fluid is thus formed for the evolution of the leaves. At this period, nutritive action is of extraordinary intensity, and the ascent of sap proportionally rapid.

Another cause aiding the ascent of sap has been mentioned by Cuvier;* namely, evaporation from the young boughs and leaves. But this cannot be the principal cause, since, were it so, the ascension would as well take place in a dead plant as a living one;—and a dead plant differs from a living one, merely in the total cessation of nutritive action.

That the ascension is not caused by any *vis à tergo,* is sufficiently proved by a fact related by De Candolle.† If a branch of willow and of many other trees be cut and placed in water in an inverted position, it will absorb the fluid, and the sap will ascend in a direction exactly contrary to the natural one. In fact,

* Comparative Anatomy, vol. i. trans.

† Physiologie Végétale, tom., i. p. 64. See also an experiment of Hales, same work, tom., i. p. 86.

if a slip of willow is placed in the earth in an inverted position, it will live, grow, and flourish, if circumstances be favourable.

The intense derivation of fluids into the plant by the sudden increase of nutritive action in the spring of the year, will necessarily cause all parts to expand, and there will be elastic reaction on the fluid. The pressure which this occasions perfectly explains an experiment of Hales. He cut off the top of a young vine, and applied a glass tube which closed around it. He found that the fluid in the tube rose to a height equivalent to a column of water of more than 43 feet, and consequently greater than the pressure of an additional atmosphere.*

Local increase of nutritive action in Plants.—We have local increase of nutritive actions in animals from injuries purely mechanical. This is termed "inflammation." No such phenomenon can occur in vegetable life from the same kind of cause; but it may occur from other causes. Richerand mentions the following case which he terms a very curious one.†

"A vine, trained against the eastern wall of a forge, shot into the building a few branches. These branches, which entered by straight enough passages, were covered with leaves in the middle of the hardest winters; and this premature but partial vegetation went through all its periods, and was already in flower when the part that remained without was beginning to bud with the spring."

This phenomenon is exactly similar to what we observe when we place one hand in a basin of cold, and the other in a basin of hot water: nutritive action will be increased in one hand, and diminished in the other; and the consequences will be, there will be more blood elicited into the first, than into the other hand. In the one there will occur redness, increase of heat, slight tumefaction, strong quick pulse; and in the other, pallor, coldness, shrinking of the tissues, and a small pulse, equally frequent with that in the other arm, but without its quickness.

* This experiment has been repeated and verified by Messrs. Niosbel and Chevreuil.

† Nouveaux elemens de physiologie.—*Prolégomènes.*

The emptiness of the arteries after death is another phenomenon well deserving attention. It is unquestionably caused by the elicitation into the tissues of the arterial blood, after respiration has ceased, and the heart has stopped beating. For nutritive action does not entirely cease when those functions do: we have proof of it in the growth of the beard and nails after death—moreover it would be impossible for the last beat of a dying heart to drive the blood through the distant capillaries; and the arteries themselves have no powers of contraction, save that of elasticity upon the removal of a distending cause.

In certain cases, however, the process of nutrition in the distant tissues does cease, before the heart or lungs cease their functions. In such cases, from the principles laid down, we ought to expect to find the arteries engorged with blood. And is not such the case in deaths which occur during the collapse of cholera, in the cold stage of intermittents, from lightning, from concussion of the brain, or any other violent injury followed by immediate death?

Some experiments of John Hunter.—This celebrated man performed several experiments which strongly illustrate the powers exercised by the chemical action of nutrition.* He transplanted the tooth of a dog and set it in the comb of a cock, where it became firmly fixed. He transferred, also, a gland taken from the abdomen of a cock, to a similar situation in the belly of a hen, where it became attached. He transferred the spur of a young hen to the leg of a cock, and vice versa, the spur of a cock to the leg of a hen; and they both grew and were nourished.

These facts are striking, but really not more curious than the grafting of trees, a phenomenon of precisely the same sort. The *vitality* of the separated part is preserved; absorption of nutritive fluid from the neighbouring parts, ensues; nutritive action—in other words, *life* with its essential phenomena, follows.

The same principles will apply to the explanation of some other phenomena, which we shall here group together.

1. The organization and conversion into the different tissues

* J. Hunter's works. See also, Abernethy's Lectures.

of coagulable lymph and extravasated blood; together with the formation of new vessels therein.

2. The enlargement of the arteries of the uterus after conception.

3. The enlargement of arteries leading to increasing tumours.

4. The violent hemorrhage which ensues when inflamed parts are divided.

5. Difference in the pulse of the two radial arteries in cases of whitlow, etc., etc.

Forces of the Circulation.—In plants and in the lower orders of animal life, there is, properly speaking, no circulation of the nutritive fluid. From certain canals or cavities in which digestion takes place, the lower orders of animals absorb the fluid which nourishes them—nutritive action occurs; and the refuse is thrown off as excretions.

In the higher animals, however, there exists a distinct organ (the heart) whose office it is to propel the arterial blood, by constant rythmic action, through a system of tubes admirably adapted for the purpose, into every portion of the living body. These tubes finally end in a net-work of exceedingly minute and delicate vessels, which anastomose in a thousand ways, and from which the molecules of the tissues absorb the nutritive fluid, through the thin delicate serous coats of which they are composed. These vessels are the *capillaries*, which finally terminate in *veins* in the same manner as they took their origin from the arteries. The blood changed in chemical constitution at the tissues is returned by the veins to the heart, whence, after passing through the respiratory organs and being subjected to the influence of the atmosphere, it is again propelled into the tissues.

But it is obvious from the facts stated above, that the heart is not the sole force maintaining the circulation, since the same principles will apply to animals possessing such an organ, as well as to plants and animals without it. Indeed they will apply with greater force, because the intensity of nutritive action is greater in the higher orders of animal life than in the lower.

If we required further proofs of the fact, they are easily found in the phenomena of blushing, erection, inflammation, etc., etc.*

A question arises: why are the superior animals in need of a mechanical agent like the heart, whilst plants and the inferior animals require no such assistance? The answer is to be found in the peculiar character, the highly chemical compound constitution of the tissues in the higher animals, and particularly that of the nervous substance. If the arterial blood be arrested at the heart one pulsation; syncope inevitably follows. The nervous matter will not bear the absence of the arterial blood one second;—to perform its functions that fluid must be present. The necessity of such an organ as the heart, is then at once seen; for had the superior animal, organized as it is, to depend like vegetables and the inferior animals, on the slow absorption of the nutritive fluid, there could have existed no such functions

* "It is not a little curious that those physiologists who deny that the capillaries have any kind of influence on the motion of the blood through them, are driven, by the force of the facts to which we have alluded, to make certain exceptions, in which nearly all is conceded that is demanded by their opponents. Thus, we find Müller stating that the movement of the blood is entirely dependent on the action of the heart, and presently afterwards alleging the existence of an attraction or affinity between the blood and the solids which it supplies, in the 'turgescence, turgor vitalis, or orgasm,' which is observed to take place in certain parts of the body, independently of the heart. He cannot conceive how such an attraction can become one of the regular moving forces however, since it would cause congestion, by rendering the blood stationary in the capillaries, 'unless,' he adds, 'it be again admitted that this attraction of the capillaries for the blood is exerted only while the blood retains its arterial character, and ceases when it becomes venous.' Now, that this hypothesis is the true one, is, we think supported by a pretty strong body of evidence. It is well known, that when there is any local excitement to the processes of nutrition or secretion, an increased flow of blood towards the part speedily takes place; and not only this, but an increased circulation of blood *through* the parts occurs, quite independently of any altered action of the heart. This we find to be the case at puberty, as to the whole generative system; during pregnancy, with regard to the uterus; during lactation, in the mammary glands, probably with regard to the brain, also, when its functions are unusually, but normally excited; and during the formation of new parts in the embryo."—*British and Foreign Medical Review, July*, 1839.

The capillaries are merely conduits for the blood, and exercise no particular influence over it. The effects attributed to the capillary vessels are caused by the nutritive process.

as those performed by its nervous matter. Insects will live for months, deprived of air and aliment: worms, if divided, will form two or more living beings. In the higher animals, we see no such phenomena: the nervous matter in them is differently organized; it is more of a whole; one part more dependent on other parts,—slight impressions at any one point being felt throughout the entire system. There was then, an absolute necessity for the existence of a permanent relation between the nutritive fluid and the nervous matter;—a relation which should be subject to no interruption, though the supply of crude aliment should be delayed for days; and that is done by an organ, which pulsating at regular intervals, keeps the nervous matter and the other tissues constantly supplied with arterial blood.

CHAPTER VII.

ADYNAMIA.

In an individual who has just suffered the infliction of a violent injury, we find among other symptoms, that his skin is icy, cold to the touch, clammy, shrivelled, and deadly pale. As this condition is general, it must have been transmitted from the seat of injury; and as we see similar effects produced by mental affections; as we can produce them by experiments made directly on the nerves; and above all, as we never observe such phenomena in any beings except those which possess a nervous system; we must attribute this sudden and appalling change to some alterations which that system has undergone.

I have elsewhere stated my opinion concerning the nature and *modus propagandi* of this change in the nervous substance, and I shall now proceed to apply those ideas to the subject before us.

In the case already instanced, we have seen that the surface is pale and shrivelled. This evidently indicates that there is less blood in the skin than usually exists there; and also that the tissue has diminished in volume, or in other words, it has contracted. The surface is also cold, denoting a diminution of chemical action; for animal heat, like the production of heat everywhere, is developed during the passage of bodies from one state to another.

Most of the animal tissues, as every surgeon knows, are highly elastic;—particularly so are the cellular, muscular, and yellow fibrous. This property they receive from their structure;—a peculiar arrangement of the particles which compose them; just as the same cause gives elasticity to steel and other bodies. The contraction, then, may be induced by elasticity; but before this power can operate, a distending force must be removed. This distending force is undoubtedly the blood, permeating and infiltrating the molecules of the tissue.

I have elsewhere shown how the arteries are emptied after death, by the continuance of nutritive action, thereby, of absorption. I have shown how this chemical action operates in producing phenomena attributed by Bichat and others to some mysterious powers exercised by the capillary vessels. But nutritive action as it occurs in health, depends on a certain condition of the tissues. If they be changed in chemical constitution; or if the arrangement of the molecules which compose them, be disturbed, a change of nutritive action may *à priori* be anticipated. I have shown besides* that the rapidity with which a fluid is absorbed by a solid, is dependent in a great measure on the intensity of the chemical actions undergone between the fluid and the solid. The quantity of blood, therefore, at any time in the tissues will depend in a measure on the intensity of nutritive action. In the case before us the quantity, as all the appearances indicate, is less than in health. This is an effect which cannot be attributed to diminished action of the heart, for, as I shall presently show, it is sometimes local; and besides, we frequently see inflammation (the exactly opposite condition) existing with an equal want of power in the heart. The diminished quantity of blood in the tissues must, therefore, be caused by a diminution of nutritive action.

The final question now presents itself. What has caused this diminution in the intensity of the nutritive process? The answer is, that the nervous matter diffused in the solids, and hence a part of them, has undergone in its chemical constitution, a

* Chapter vi. Aph. xii.

change, which has rendered every tissue affected, a substance different from what it was the moment before.

The particular steps of this change we know not, as they are entirely molecular, and placed, perhaps, forever beyond the reach of observation. That a change has occurred is obvious; and that it is of chemical nature, no one we think, who attentively considers the phenomena, can for a moment doubt.

But what becomes of the blood existing in the tissues at the time the injury was received. Will it not from its very existence there, oppose the reaction of elasticity?

In health, the presence of arterial blood in the tissues is caused and kept up by two forces:—1st, the action of the heart, and secondly, nutritive action. These forces are sufficient to overcome to a certain extent the cohesive force by which the molecules of the tissues are held together; in short, the tissues are expanded and are kept so by the non-intermittence of the two powers which act. It must also be kept in mind that it is *arterial* not venous blood, which is attracted into the tissues in consequence of the chemical actions there going on. Suppose now that one of these forces be suddenly diminished; let it be that of nutritive action; the action of the heart remaining as before. The influx of blood is of course diminished; the elasticity of the tissues has to contend not with a strong advancing current as before, but merely with the quantity already in the tissues. The equilibrium of forces is destroyed, and as the distending force is diminished, the tissues must of necessity contract; and the blood contained therein, will be forced into the veins, towards which there is a free and open passage; and this contraction will continue until it has reached its natural limits, or is opposed by the blood impelled by the action of the heart.

To turn back on our steps. The series of phenomena as they occur are these. A change occurs in the nervous matter affecting its chemical constitution, and consequently, that of the tissues. The relation which the tissues bear to the nutritive fluid is altered;—the nutritive process is diminished in intensity or entirely arrested; less blood is attracted into the tissues; the distending force being thus removed the molecules of the tissues

approach each other, in other words, they contract; and the blood is forced, first into the capillary vessels, then into the veins. As the nutritive process is nearly arrested, coldness is a necessary consequence. The shrunken state of the skin, and indeed of the tissues generally, is explained by the contraction of the tissues; the pallor, by the absence of the blood.

These symptoms being explained, the others are easily read. The small, scarcely perceptible pulse arises from three causes. 1. Loss of strength in the action of the heart, in consequence of transmission by the cardiac nerves of the change undergone in the nervous substance. 2. Diminution of attractive force in the tissues, in consequence of the arrest of the nutritive process. 3. The diminished calibre of the arteries themselves.*

The slow and heavy respiration also arises from three causes. 1. Contraction of the lungs upon themselves, and from the same cause that produces the shrunken state of the skin;—in fact, it is the same phenomena repeated in the lungs. Hence it follows, that even if the action of the heart was unaffected, less blood would pass through the lungs than in health. But in almost all cases in which the lungs are affected, the heart also suffers. And it is well that so it is;—it is well that nature has so concatenated the organs by means of the nervous system, that they modify their actions as it were by common consent. For suppose that the heart continued to act with its usual power whilst the lungs were in this collapsed condition. Effusion of blood and serum into the air vesicles, and of course death, would be the inevitable consequence.†

It would be quite fair and philosophical to rest this assertion concerning the collapse of the lungs, upon analogy; because where circumstances are the same the effects should be the same. But we are under no necessity of so doing, for we have direct evidence of the fact. The shrunken and contracted state of the lungs must have struck every person with surprise, who

* The arteries contract from the same cause that the other tissues do,—viz. diminution of the nutritive process in their tunics.

† See, further on, the effects produced by cutting the pneumogastric nerves.

has made post mortem examinations of bodies which have died in the collapse of cholera; a disease characterized in that state by all the symptoms which mark this lesion of innervation.*

2. The nutritive process,—that is, the movement of composition and decomposition, being nearly annihilated throughout the body, there is not the same requisition for arterial blood as there is in health. And here we have another call to admire the beautiful order in which all parts of the animal system act and react on each other. For, were the functions of life going on in their usual course during this collapse of the lungs, the consequences are obvious. It would be impossible to aërate the requisite quantity of blood, and death would inevitably follow.

3. The nervous substance of the lungs existing in a morbid condition, these changes, which must be transmitted to the sensorium to cause sensation, do not take place so readily as in health;—in other words, the *besoin de respirer* is not felt.

Perhaps to these causes should be added another;—the difficulty of muscular exertion.

We frequently find patients in the condition we have described, who, though not unconscious, seem to suffer but little pain from the most serious injuries. They will permit the surgeon to dress and handle the wounded parts without a murmur. This impassiveness to impressions must proceed from the cause already mentioned in regard to the transmission of sensation from the lungs. The proof that it is dependent on a peculiar condition of the nervous substance, occurs a few hours afterwards, when the nervous matter, having passed into another state, transmits impressions so readily, and accompanied with

* The contraction of the lungs during expiration occasions the rise and vaulted form of the diaphragm. In adynamia the contraction of the lungs and rise of the diaphragm is carried to a much greater extent. Majendie has proved this by experiment. "Rendez 'dit-il, visibles les mouvemens du poumon sur un jeune lapin; remarquez le point où s'arrête l'ascension du diaphragme dans les expirations les plus complètes; dans l'instant d'une expiration de ce genre, coupez la moelle épinière au cou, au moment de la section, vous verrez le diaphragme remonter d'un ou même deux intervalles intercostaux."—*Precis. Elem. de Physiologie.*

such exquisite pain, that the sufferer is struck with terror at the mere sight of his surgeon. Sometimes total insensibility accompanies this lesion. In such cases the brain has participated deeply in the molecular derangement. If the stupor be profound, stertorous breathing will occur as in apoplexy, and from the same cause; namely, the impressions transmitted from the lungs are not perceived until they grow intense.

The vomiting and diarrhœa are caused by a flux from the mucous membrane, poured into and distending the stomach and intestines. This flux is evidently one and the same phenomenon with those of the limpid urine and the clammy perspiration; for they all have their origin in the same circumstances. They are, in fact, *exhalations* not *secretions;* for they are evidently composed of the serous portion of the blood;—that is, water holding in solution a little albumen and some salts. They are formed by no series of chemical actions in the tissues, but exist already formed in the blood, and transude, as it were, mechanically through them. These exhalations are not confined to the mucous membranes, skin and kidneys; they frequently occur in the serous cavities, such as the ventricles of the brain, pericardium, etc., and they are frequently tinged with the colouring matter of the blood.

The manner in which these exhalations are formed, I take to be this. The nutritive process having been diminished, and the tissues contracting in consequence, are still permeable to the more watery portions of the nutritive fluid. Having an eye to what occurs in a dry bladder, we may even admit that this fluid is partly drawn there by absorption. But as the chemical actions of nutrition do not go on as in health;—as the arterial blood is not converted into venous in the same quantity and with the same rapidity as before; the serosity filling the tissues would undoubtedly remain there were it not for the *vis à tergo*—the pressure exercised by the constant action of the heart and arteries. To escape this pressure there are but two ways: the passage through the capillaries into the veins; or through the tissues into a cavity, or outwardly. During health the fluid takes, in a great measure, the first; being controlled by the

other elements of the blood, which are elicited into the tissues and kept there by those powerful affinities which concur in the revolution of fluids into solids and of solids into fluids. But these chemical actions being diminished,—arrested, as it were—a condition of things occurs precisely like what takes place when we inject the arteries of a dead body with warm water:—the *vis à tergo* causes exhalations from the membranes and into the cavities. Something of the same kind occurs when a vein is tied, or when compression is made upon them by tumours. The blood not having a free passage to the heart, the serous portion is driven by the arterial pressure through the tissues and collects in the cellular membrane. This loss of the serous portion of the blood will of itself produce most important changes in the constitution of that fluid; and thus give rise to other and most alarming symptoms; but of which this is not the proper place to speak.

There is another phenomenon which always attends this lesion of innervation, if it has been severe enough to cause death. I mean the distention of the arterial system. When death ensues from inflammatory fevers, we find the arteries empty;* but when it occurs with the nervous substance in the condition we are now speaking of, we find them full of blood. This is a necessary consequence, for the blood not being absorbed by the tissues must remain in the great vessels. Hence, we find in every case of cholera in which the patient dies in collapse, the arteries crammed to the heart. The same state of the arteries is found in those who die in what is called "congestive fever;"—it is also met with in persons killed by mechanical injuries at once and without loss of blood; in those killed by lightning, narcotic poisons, etc. It is also found in those who die in the cold stage of intermittent fever.

The arrest of the nutritive process in the tissues cuts off the circulation in a great measure at the capillaries; for the heart cannot, though it may beat strongly, keep up the current as in

* From this fact the arteries take their name.—αερα τηρειν.

health. All know how difficult it is to get blood from a vein in collapse of cholera, or in intermittents of the algid type.

Causes of Adynamia.—Physical injuries, such as blows, gunshot wounds, extensive burns, etc., all produce this condition of the nervous substance. When caused by a blow on the head, the brain is more than usually implicated, and it has hence been called by surgeons *concussion.* Yet the same condition of the system is apparent after all great injuries. Patients are frequently thrown into this condition by severe surgical operations, and death in consequence thereof has been termed by English surgeons—*death without reaction.** But the production of this lesion is not limited to sudden shocks or mechanical injuries. Many of the narcotics, as digitalis, hydrocyanic acid, the salts of morphia, etc., produce, by chemically altering the nervous substance, a state of the body marked by the same general traits. In physiological experiments, the effects of laudanum in putting a stop to the circulation in the web of a frog, are well known.† Certain passions and emotions, as apprehension,

* "A frog was made insensible by the application of laudanum or alcohol. Its respiration ceased. It did not move on the application of any irritant. The circulation in the web was carefully observed. When it had long continued in the same enfeebled state without change, the thigh was crushed. The circulation in the minute and capillary vessels ceased at once and never returned. The stomach was now crushed in the same manner. The heart ceased to beat for many seconds. Its beats then returned,—but never regained their former force. The effect was precisely *such as was observed by Legallois, on crushing the spinal marrow.* There was not the slightest indication of pain in either experiment.

"The experiment was repeated. The result was so perfectly similar, that a note was written, at the time, stating that the experiment need not be again repeated.

"Nevertheless it was repeated several weeks afterwards with precisely the same results. The action of the spirit upon the cutaneous surface had arrested the respiration, destroyed all sensation, and induced considerable languor in the circulation of the web. When this state had continued uniform during a considerable time, the other limb was crushed by a hammer. There was not the slightest motion of the animal or expression of pain, so deep was the insensibility. The circulation in the whole web ceased instantly."—*Essay on the Circulation, by Marshall Hall*, p. 123.

† See experiments of W. Philip, M. Hall, Thomson, etc.

horror, terror, intense anger, etc., produce similar affections of the nervous substance. So also do some mineral salts, as antimony; miasms and contagion also produce it. The unknown cause of cholera is another producer of this lesion, and a most effective one. Copious bleeding is another cause.

But above all, cold has a marked tendency to bring on an adynamic state of the system, as is evidenced in the shrunken appearance and pallor of the skin in bodies exposed to severe cold; also, in the increase of exhalations from the bowels and kidneys, and in the diminished secretions. The pulse is also affected, becoming small and slow; the intellect is torpid; in short, all the functions of life are diminished in intensity. But perhaps the influence of cold in producing this lesion may be better set forth in its local effects. If a part of the body,—the knee, for example—be exposed to cold whilst the other parts remain protected, violent reaction will ensue should the individual imprudently venture near the fire without taking the precautions usual in such cases. He will have an attack of rheumatism in the knee; and it is plain that the warmth of the fire, though the immediate, is not the sole nor even the principal cause, of the phenomena. Now, inflammation we shall soon show, is dependent on irritation (the secondary lesion of innervation;) and furthermore, the inflammation could never have occurred, had the cold been continued. The parts might have died; but nothing like inflammation could have occurred under such circumstances. The nervous lesion which accompanies inflammation must, therefore, have been subsequent to another lesion, and this primary lesion (adynamia) was produced by the abstraction of heat.

The older pathologists used to explain this effect of cold, by saying that it increased the *excitability* in the parts on which it acted. When local, as in the case just instanced, the excitability was *divided;* that is, more of it was accumulated in the affected parts than elsewhere, and hence those parts were more disposed than any others to violent reaction on the accession of a stimulus. This was their mode of reasoning in ordinary cases; and indeed it was so far good, as they limited themselves to a

mere expression of the phenomena. But as men are ever disposed even unconsciously to frame entities out of attributes, or even out of mere states or conditions, they found it difficult to explain how it was, that cold, which *increased* the excitability in ordinary cases, should, if carried a few degrees further, quench it altogether, by putting an end to life.

Local Adynamia.—I have already said that this condition was sometimes local. In truth, it is self-evident that in a general affection of the system from a mechanical injury, there must have previously existed a local affection of the nervous substance to bring it on. In cases of complete prostration from severe wounds, it is obvious, that the general affection is a consequence of an impression made on the nervous substance in the wounded part. There is nothing, therefore, to interdict us from considering this lesion as we do irritation;—namely, that it is sometimes local and sometimes general. Indeed if we pay attention to what occurs immediately previous to the setting in of inflammation, I think we shall find that the lesion we are at present speaking of, is almost always the forerunner of that other lesion on which inflammation depends. The sting of a bee causes pallor of the tissues, which become red only subsequently. In burns not severe enough to affect the constitution, every surgeon must have been struck with the extreme pallor of the injured parts immediately after the accident. In many cases of lacerated wounds, it is necessary to apply stimulating applications to prevent what surgeons call, "death of the part without reaction." How often has it been the fate of the physician to be disappointed in the anticipated effects of a blister? To find, instead of a secreting surface with injected capillaries, one clammy, white, and dead-like? He sometimes sees certain parts of the body, as the ears, nose, fingers, etc., turn of a sudden very white and cold. The same condition of the tissues occurs also just before an attack of gout. These are cases of what pathological anatomists call "local anæmia;" but this is plainly merely a symptom and a consequence.

I will here quote a passage from Andral. Among the causes of local anæmia he gives the following: "Certain modifications

of the nervous influence which so materially affects the greater number of organic phenomena. Thus, under the influence of a strong mental emotion, the blood suddenly flies from the cutaneous capillary vessels of the face, or of the whole surface of the body; and what is well worthy of attention, is, that the very same impression which in one individual causes the blood to recede from the surface, will, in another, cause it to rush with impetuosity into the superficial vessels: accordingly, we have all observed that a deadly paleness or a crimson flush may indifferently succeed to an excess of passion or a strong emotion of terror.

"These phenomena, trivial as they may appear, are nevertheless deserving of our attention for the light which they throw on the interpretation of certain phenomena, that occur in other and more important organs under the influence of the same causes. Why, for instance, may we not suppose that under the influence of similar causes, the stomach may blush like the skin, or like it turn pale? In these cases the anæmia is only momentary; but if the nervous cause which has once produced it be often repeated, this state of anæmia may become habitual, and thus produce, for instance, the pale complexions so frequently observed in men whose minds are constantly engaged, who are tormented by violent and agitating passions, or who are of what is generally termed a nervous temperament, even though no organ be deranged in its structure or function."*

I have limited myself to the proposition that generally this lesion of innervation precedes that called *irritation*. This is as much as I think we are warranted in saying. Whether in all cases of erection, inflammation, etc., a prior condition of the nervous substance does or does not exist, must be a subject of investigation. Some facts on the subject of sensation seem to support the opinion, that the adynamic state always foreruns the hyperdynamic; for in many cases, there intervenes a perceptible portion of time, between the moment of contact and the sensation. This is observable more particularly in the sense of

* Anatomie Pathol. Tome i. art. Anæmia.

hearing; to effect which, it can be proved that a series of changes in the substance of the acoustic nerve is requisite. However, it must not be forgotten that we are not to reason on this subject à priori; for there is nothing, except in the facts observed, to hinder us from considering the nervous matter as fit in certain cases to pass at once, and without any intermediate change, from a state of health into that of irritation.

CHAPTER VIII.

ON HYPERDYNAMIA—OR IRRITATION.

The law "*ubi stimulus ibi affluxus*" has been received by the greater part of physiologists as ultimate in nature;—as one of those general principles which when we reach, we must rest satisfied with, since there is no advancing beyond them. In many theories, it has been taken as a basis on which the superstructure was to be erected. In doing so they have evidently followed the example of those who have explained muscular motion by attributing it to the property of *irritability;* as if irritability itself was not the result of certain conditions—as if it was not a thing dependent, and, therefore, requiring explanation. That there will be an afflux of blood to the parts on which certain substances are applied, is a truth in many cases, but not in all, for we know that the living body may be in a condition, that such an effect will not be produced. In the collapse of cholera, for instance, even epispastics, sinapisms, etc., will cause no afflux of blood to the parts on which they are applied. How often has it been the fate of physicians and surgeons to find their blisters instead of producing a fine red injected surface, to meet on the contrary with a cold, pallid condition of the parts, with a little watery serum issuing from them! The truth is, these *stimuli* will, in many instances, pro-

duce an adynamic condition; of which, Sabatier, in his little work on revulsion, has recorded many instances.*

The word *stimulus* has been applied to a number of substances, which when they come in contact with the living animal, *existing under certain conditions*, cause an increase of nutritive action in the parts they touch, and in consequence, an increased flow of blood thither. Stimulus therefore is a relative term, and whenever we employ it we must do so with reference to its co-relative—namely, the living body existing in certain conditions. Broussais has defined stimulus to be every thing which increases the phenomena of life, but it is obvious from this definition, that the word cannot be applied invariably to any one substance in nature, for no substance is a stimulus in all cases: indeed in many cases that which increases nutritive action in one person, will cause effects directly opposite in another; nay when we come to the subject of ataxia we shall see, that the very same substance acting on the same subject, will produce opposite effects, if the quantity administered be increased beyond certain limits. "Heat" says Broussais "is the first and most important of stimulants," but even heat is not a stimulant in all cases, for what surgeon has not witnessed the small pulse, cold skin, white surface—in one word, the complete adynamia produced by an extensive burn.

The law "ubi stimulus ibi affluxus," is therefore, not ultimate in nature. The increased flow of blood into the parts is a phenomenon depending on certain conditions for its existence. It is therefore a subject for study; and in order to explain it, we must find out those circumstances which attend and which precede it.

In a former chapter it was shown that the actions of nutrition, going on throughout the body, caused a constant derivation of blood into the tissues; and the principle was illustrated by the example of combustion in the wick of lamps, wherein it was demonstrated that in proportion as the products of combustion were removed, was the afflux of fluid up the wick.

* Les Lois de la Révulsion, etc., par J. C. Sabatier.

But the quantity of the products removed will depend on the intensity of the chemical actions going on, and therefore it follows, that whenever we increase the actions of nutrition we shall have an increased flow of blood into the tissues.

But nutritive action may be increased in some particular part whilst in the other portions of the body, it remains in *statu quo*, or is diminished. When this occurs, the equilibrium of action in the system being destroyed, unusual phenomena will present themselves. The increased quantity of blood will cause tumefaction and redness, the increased chemical action will cause an increase of heat, and the morbid condition of the tissues will affect the brain through the medium of the nerves, and we shall have exalted sensibility. This condition of things within certain limits is termed *erection*, beyond those limits *inflammation;* and it will be seen at a glance, that the phenomena which characterize them, are directly opposed to those of adynamia. In the former we have increase of heat, redness, tumefaction and exalted sensibility;—in the latter, coldness, pallor, contraction of the tissues, and loss of sensibility.

Here then we have all the phenomena following necessarily upon the occurrence of increased nutritive action in the tissues. What causes this increase of action? common sense would inform us that when the actions occurring between two substances are altered—increased or diminished, one of three things must have occurred, either one or other of the substances themselves has undergone a change of condition, or some third substance has intervened: either the blood has changed, or the tissues have; or some external agent has interposed. Neither the first nor the last can occur when the lesion accrues from mechanical agents; the tissues therefore have themselves changed; and this change as we have already pointed out can only be a chemical one; and follows from that disposition of animal substance, to take on isomeric changes, when the arrangement of their respective molecules are interfered with.

We have already shown that this affection is almost always preceded by Adynamia—The causes which bring about this after change—this passage from one condition into another di-

rectly opposite are obviously of two kinds, 1st, those internal chemical actions which take place in all animal matter when left to itself, and, 2d, the change of relation which occurs between the arterial blood and tissues, when these last are in the adynamic state;—a circumstance naturally productive of further change in the material of which the tissues are composed.

The tissues then pass out of Adynamia into a new state which I have termed Hyperdynamia; and which is designated by most authors by the word Irritation, though in truth, many of them use it very indefinitely and vaguely, sometimes meaning by it Ataxia and sometimes even Adynamia.

Now let us observe the effects of Inflammation.* The effects will vary in the first place according to the intensity of the actions going on; and vary not only in a mechanical sense but also in a chemical point of view: sometimes the inflammation will disappear leaving but a few traces of its existence; at other times the parts are left soft, flaccid and discoloured; in other cases we have effusion of pus; in others the fibrinous portion of the blood oozing through the tissues is deposited as "coagulable lymph;" and finally we may have gangrene.—The intensity of the inflammation is in fact only an external sign of the extent of change undergone by the tissues; and of course the effects will differ accordingly. In all highly compound bodies we cannot increase or diminish chemical action and at the same time effect nothing more than increase or diminish the quantity of the same productions; for at the same time that we increase the actions we alter the results. Hence inflammation involves not only *increase* of action, but also *perverted* action. The results differ in kind from those of healthy action, and this is an important fact which should never be lost sight of.†

The first effect of irritation is to cause an afflux of blood into the tissues. This increased quantity of blood and the increased

* The word "Irritation" simply expresses the condition of the tissues:—inflammation expresses not only the condition of the tissues but the consequences also, such as increased derivation of blood to the part, etc.

† Observe the immense differences in vegetables, caused by mere differences of temperature.

force by which it is elicited, will necessarily have the effect of enlarging the capillary vessels (or spaces.) Not only this, the capillary vessels have in health a relation with the quantity of blood to be supplied to the tissues—that is, with the force by which they attract it. Now this force being increased, there will be new capillary spaces formed by the blood itself forcing a passage to unite molecule for molecule with the tissues. When the inflammatory action is slight, the tissues return to a healthy state without being much changed in appearance, but in other cases we have continual redness of the parts for a long time after the action has subsided, accruing from the previous enlargement and increase in the number of the capillary vessels; and also, from a real loss of substance in the diseased tissues. The tissues in this case, it is said, lose their tone. In truth they are *rarefied*, their density is less than before. Hence they lose in some degree their elasticity, and they are kept distended with blood by the action of the heart.

Pus is a secretion from inflamed parts. It never occurs at the commencement of inflammation; nor even while the action continues high: it makes its appearance when the disease is on the decline. The peculiar circumstances on which the formation of pus depends, are unknown, as likewise are those of all the other secretions. One thing must however be taken notice of: pus is a secretion which all the tissues may furnish after being inflamed. Hence, probably, the small alteration necessary to be undergone by the blood to furnish pus—for pus seems to be the serum which has undergone some peculiar chemical change.

Globules are found in pus as in the blood, and they have been thought to be identical, but this is not probable. Because in the first place the globules of pus are larger than those of the blood, and in the second place, it is impossible to conceive how bodies so large could penetrate the tissues intermolecularly as occurs in all cases of secretion. The most probable opinion is that the globules are formed after the secretion has taken place.

Coagulable lymph is even nearer to blood than pus:—for it is, strictly speaking, nothing more than the fibrine of that fluid

exhaled in a fluid state and afterwards coagulated. Abstract the colouring matter and the water of the blood, and coagulable lymph remain behind. It appears to me to be a true exhalation, occurring under circumstances which we know too little about organic chemistry to estimate.

Coagulable lymph is the plastic matter of animal life, it is the only substance in short, capable of being converted into the different tissues. It therefore plays an important part in all cases of renovation, as adhesion, granulation, the renewal of lost parts, etc. Effused into the substance of organs, it increases their consistence and they are said to be hepatized; poured out on the surface of membranes, it forms what are termed *false membranes.* Organizable, but not yet organized when first effused, it becomes a tissue by solidification, and absorption of nutritive fluid from the parts with which it lies in contact. In this state, it may be compared to a seed placed at the proper season in the earth; it absorbs, it assimilates, it secretes. In other words all the actions of life take place within it. It may, therefore, itself take on the phenomena of the disease; it may become irritated and inflamed and pour forth pus, or any other morbid secretion.

The next phenomenon to be explained is gangrene. All parts of the living body require a continual supply of arterial blood. If this supply be cut off for any length of time, the elements of the tissues will react upon each other, giving rise to productions essentially different from those which occur when arterial blood is present. In short, decomposition takes place; gaseous and liquid substances are formed from the solids which gradually disappear in the process. Gangrene is the decomposition of inflamed tissues, and occurs in consequence of the supply of arterial blood being cut off. How is it cut off? We have already pointed out the distention and engorgement of the capillary vessels in consequence of increased quantity of blood attracted into the tissues. But the blood is not a simple fluid, it is composed of solid substances held in solution; now it is evident that in the endeavour to reach the molecules of the tissues, the more fluid parts of the blood will pass more easily than the globules. As

soon as this takes place the fibrine coagulates, thus blocking up the capillary spaces and effectually preventing the access of arterial blood from the heart. The elements of the tissues then react upon each other and we have gangrene. Any thing in fact that prevents the influx of arterial blood, will in the end produce gangrene, whether the parts be inflamed or not: thus, Cruveilhier produced it by injecting quicksilver into the capillary vessels. It may also be produced by preventing the return of venous blood, and thus causing a congestion in the tissues. In very old people in whom the actions of nutrition are greatly diminished as to intensity; congestions of this kind sometimes occur in the lower extremities giving rise to what is called *gangrena senilis.* The gravitation of the blood here becomes superior in power to one of the forces which return the blood to the heart; namely, nutritive action. That such is really the case, is evident from the fact that merely placing the limb in a horizontal position is sufficient to relieve the disease, if taken at the commencement.

So much for the *usual* effects of inflammation. But there are phenomena of a very different character that may attend or follow it. In truth, there is not a change of structure or a lesion of secretion which may not make its appearance during the progress of the disease. Hence we may indifferently meet with hypertrophy, atrophy, induration, softening, ulceration, transformations of various kinds, tubercle, melanosis, encephaloid matter, etc., either as accompaniments or sequelæ of inflammatory action. The determining circumstances, the proximate cause, *that without which the disease would not be,* is in every one of these cases utterly unknown. Most unphilosophically it is often said and repeated that irritation is the cause of these lesions; but they frequently occur where we have no proof whatever (indeed in some cases we have proof of the contrary) that there has existed any inflammation during the whole course of these lesions, yet even if this were not so, it would be illogical to ascribe these effects to irritation. For if irritation causes *induration* what causes *softening?* If it causes *hypertrophy,* what causes *atrophy* or *ulceration?* To tell us that

irritation is the cause of all of them is to pay us off with mere words. Nor can it be said, that these various lesions are caused by irritations of different intensities, for we may increase or diminish irritation *ad libitum* without being able to produce any particular one of them. In short, those who refer all those various results to irritation as their cause, have not well fixed in their minds what they mean by the term. In some works it actually has the same signification as the word *disease*—and when they tell us that such or such a lesion is caused by irritation, they really tell us no more than that the alteration of structure has been caused by diseased action. This kind of philosophy is very cheap, and at the hands of every body; and moreover it saves much trouble of investigation; but it is not what a lover of truth will be easily satisfied with. The term *irritation* expresses to us *a condition of the tissues which is manifested by increased nutritive action;* and nothing more. Now this increase of action may occur in tissues placed in other respects under circumstances very different; and these circumstances, which in many cases we overlook, but in the great majority cannot appreciate, are really the determining causes of the phenomena we witness, the *sine qua non* which makes *this* a case of ulceration instead of hypertrophy; and *that* a case of induration instead of softening. All that we can legitimately say then, in regard to this subject, is this,—that irritation frequently attends, or precedes these lesions.

Individual peculiarities, which we do not understand, yet know to exist, influence in a great degree the appearance, course, and effects, of inflammatory action; the tissues of persons of a scrofulous habit, or disposed to scurvy, exhibit peculiar traits and characters when inflamed. So, also, that inflammation called erysipelatous, may make its appearance on the skin from the slightest scratch. It is impossible to point out the cause of this, we know, however, that it is frequently connected with affections of the gastro-intestinal canal. A similar scratch in another person would end in a horrid ulcer—in a third would heal without trouble. Here are different effects from the same cause, but the circumstances in which the difference depend,

we are not acquainted with; it should be our study however to discover them.

When a tissue or organ is inflamed, the proper secretions of the part may be increased, diminished, or perverted. And here again individual peculiarity is strikingly evidenced by the different effects produced by the same cause, acting on different persons. A slight irritation of the nasal mucous membrane, caused by exposure to the same degree of cold, may produce in one person a flow of watery secretion; in another all secretion will be arrested; in a third we have increased secretion of mucus; in a fourth we shall have hæmorrhage. Some persons are particularly disposed to these bloody fluxes from various parts of the mucous tissue. Hence we have hæmatemesis, epistaxis, menorrhagia, hæmaturia, or hæmoptissis; according to the location of the tissue. We can trace nothing in the organization of the tissue, or in the blood itself, to link the effect with the cause. "Twenty-eight soldiers," says Dr. Johnson, in his work on Tropical climates, "were employed at work in the neighbourhood of an extensive marsh in America; every one of the party fell sick, but not all of the same complaint; three died of cholera, five of dysentery, four of adynamic fever, accompanied with yellow colour of the skin, and all the others were seized with intermittent fevers of a malignant character.

Those substances called poisons, give a distinctive character to the inflammations they produce. The distinctions, however, are of a general character—for in this as in all other cases, the course of the inflammation will be modified by the attendant circumstances. The poison of small-pox, of measles, of syphilis, each produces an effect distinguished by generic characters, but, are all subject to a thousand minor differences. Twenty individuals catch the venereal disease from the same woman, yet all differ one from another in some respects. It is an idle thing to expect absolute similarity. All the circumstances we have mentioned above, will modify in some respects the action of external agents and the effects produced by them—it must be kept in mind that the same cause acts upon *different subjects*. To point out the distinctive differences, etc., of these inflammations,

belongs to the province of special pathology; we are merely treating of general principles.

As has been shown in another place, the condition of a tissue may be propagated along the nerves to the rest of the body, and thus a local affection becomes a general one. The general affection consequent upon inflammation is *fever;* and it must necessarily differ in one respect from the local affection. The quantity of blood cannot be increased in the tissues generally;—such a thing as a general inflammation being utterly impossible. For in the local affection, the increased quantity of blood in the parts is obviously taken from the general stock contained in the blood-vessels; so that the rest of the body must receive a portion less than before. Therefore, to increase the quantity of blood in *all* the tissues at once, is impossible, unless it be introduced from without.

But though the tissues generally cannot receive an increased supply of blood, they evidently manifest the increased power with which they attract it. If in a local affection, the pulse of the artery going to the part be examined, and compared with that of other parts, a manifest difference will be at once observed. Feel, for instance, the radial artery going to the hand affected with whitlow; and compare the pulse with that of the other hand. It will be found tense, full, quick; whilst the other is perfectly healthy. The reason is, that in the first case, the blood, in addition to the impulse given by the heart, is drawn by a violent suction power into the tissues;—a power, which always exists during life, but in this case is highly increased. Now suppose increase of nutritive action to occur universally in the tissues; the pulse of the affected arm would become general; we should have the pulse of fever.

Erection, inflammation, and fever, are, therefore, merely degrees of the same affection.

Concerning fever and secondary inflammations, I shall have something to say hereafter.

CHAPTER IX.

ON ATAXIA.

The blood may remain unchanged at the time that the tissues undergo the isomeric changes which we have just treated of. The blood, indeed, is seldom affected primarily; the changes it undergoes are consequent to the changes undergone by the tissues. But when the tissues are altered in chemical constitution, their relation with the blood is also changed, and hence we have a series of effects different from those we usually observe.

Life is maintained by a certain number of exterior agents, among which, those termed *aliments,* are of the first importance. From them the blood is formed, and subsequently the tissues. A periodical supply of food is required because the blood is expended in the different phenomena of life: if this supply be withheld a series of morbid actions commences, and if it be continued, death ensues.

This morbid condition is characterized by certain phenomena, and is termed Ataxia.

We have already enumerated those phenomena, and a glance at them is but necessary to show, that the chief characteristic of Ataxia, is a remarkable increase in the facility, with which the tissues undergo isomeric changes. The great irregularity of the symptoms (such as the alternations of chills and fevers; the irregular distribution of heat; the inconstant fluctuating se-

cretions; the morbid exalted sensibility, etc.,) is but the consequence and manifestation of this increased liability to isomeric changes. In this condition, causes which would produce scarcely a perceptible effect in health, are attended with tremendous consequences; the opening of an abscess, the introduction of a catheter into the urethra; a fit of passion etc., producing frequently nervous delirium, subsultus tendinum, and sometimes death itself.

In this condition the chemical constitution of the nervous substance is affected, not as in adynamia and hyperdynamia, by a mere isomeric mutation, (that is, without the addition or abstraction of foreign substances,) but by a real change in the material of which it is composed.

In health the blood and the tissues have certain relations which keep up a certain series of regular events. But when those relations are destroyed, as in disease, or (when aliment is withheld) by the organic actions themselves, another train of results takes place, the tissues are no longer nourished as formerly, new chemical combinations occur, and the result is this ataxic condition,—the forerunner of death.

Like a delicately balanced pendulum the tissues now oscillate between adynamia and hyperdynamia, the slightest breath of air producing a chill which is followed by a fever.

If the reader wishes a detail of cases of this condition, he may consult Mr. Travers's work on Constitutional Irritation—for his constitutional irritation is nothing more than *ataxia*.

I object, however, to the term *irritation* as applied to this condition, since that term is employed usually to denote a hyperdynamic condition—and such being the case, it is obviously unfit to represent ataxia. A man suffering from inflammatory fever is in a high state of general irritation; but he may be at the same time very far removed from *ataxia*.

Persons are sometimes born with a predisposition of this kind—a real ataxic temperament, which goes by the name of the *nervous* temperament,—slight causes affect such persons powerfully; and when diseased they require most delicate

management and unremitting attention. The digestive chill and fever is well marked in such cases.

Ataxia will present shades of difference according to the causes which produce it, and the system in which it appears. The gouty diathesis is nothing more than an ataxic condition produced by certain causes, such as indolence, high living, etc.

Delirium tremens (or mania à potu) is another variety of the same state—produced by the chemical action of alcohol upon the tissues, and particularly upon the nervous.

Nervous delirium occurring after surgical operations or severe wounds is another variety of it. The persons thus afflicted are generally constitutionally predisposed to it, either by hereditary transmission or by intemperate habits.

All fevers, from whatever cause produced, leave the system in this state, which will be of greater or less intensity, according to circumstances. Convalescence is nothing more than an ataxic condition, attended with a gradual amelioration of the symptoms. Hence the danger and frequency of relapses in persons recovering from high fevers.

Organs that have suffered from inflammation are left in an ataxic condition, and are hence said to be predisposed to disease.

Sudden death in consequence of drinking cold water, occurs from adynamia produced upon an ataxic state of the system. The victims have generally been previously exhausted by the heat of the weather, labour, long walking, thirst, etc.

The irritable ulcer is the manifestation of an ataxic state of the tissues diseased.

When inflammation occurs in a patient of ataxic temperament (hereditary or induced) we shall have a train of nervous symptoms accompanying it; and all those irregularities of secretion, etc., which we have enumerated as characterizing the diathesis. Hence the condition of the nervous system is one of the chief causes which influence the appearance, progress, and effects of secondary inflammations.

Ataxia (or exhaustion) may also appear in the muscles or in

the nervous substance of the special senses. Fatigue is but an ataxic condition of the muscles.

The treatment of ataxia is the most delicate that the physician can meet with, and particularly when it is combined with inflammation, to attacks of which patients in this condition are greatly exposed. On this subject I shall quote M. Andral:—"When," says he, "a patient has lost a large quantity of blood in a short space of time; when during convalescence from a tedious illness he has been long kept on low diet, or when, after an attack of acute inflammation he continues to labour under the disease in a chronic form; whenever, in short, the system has been exhausted without adequate means being taken to recruit its losses, it frequently happens that the sensibility of the nervous system to impressions is increased in the same proportion as the muscular strength and quantity of blood are diminished. Under such circumstances, a hyperæmia attended with the least degree of pain may excite the most alarming derangement in the functions of the nervous system. I have seen, in a case of this kind, the bite of a single leech produce symptoms of tetanus; it is scarcely necessary to add, that the application of more powerful irritants, such as cupping glasses, blisters or sinapisms, is still more decidedly contra-indicated in such cases. To this morbid sensibility of the nervous system must be attributed the injurious effects so frequently observed to follow the application of revulsives to persons debilitated by copious venesection or protracted abstinence from nutritious diet, not that the hyperæmia attended with more or less pain, that is produced by the revulsions, directly aggravates the original hyperæmia, but that it produces a violent effect upon the nervous system, which, in its turn, reacts upon the primary disease, and thus aggravates those symptoms which it was intended to relieve.

"This exquisite sensibility of the nervous system is not exclusively confined to persons labouring under chronic disease or reduced by tedious convalescence; there are some individuals in whom this state of the nervous system is constitutional: they

are generally persons of a delicate frame, and whose muscular system is imperfectly developed. In such cases, all our attempts to remove local congestions by abstraction of blood, only give an increased predominance to the nervous symptoms, the repetition of the blood-letting serving but to increase the convulsions, coma, delirium, etc.

"Hence it is obvious, that in our treatment of this class of diseases, the local congestion should not engross our whole attention; for the symptoms by which these congestions are attended, not unfrequently depend on some peculiar state of the blood or nervous system, which preceded and favoured their development, and consequently it is only by taking all these circumstances into account that our treatment can be either judicious or successful."*

These remarks are excellent and I have copied them for more than one reason, but principally in order to introduce some observations on the great therapeutic remedy, *blood-letting*.

For what purpose do we let blood? not assuredly for the old and mechanical reason to lessen the force of the column sent from the heart; but to fulfil two objects; first, to lessen the chemical actions going on in the tissues, in which actions blood is one of the agents; and secondly, to change the condition of the nervous system; to throw it out of hyperdynamia, if possible, into an adynamic state: it must be plain from what we have said that if we affect suddenly the nervous centres (the encephalon and spinal marrow) we shall affect the tissues generally. Hence the advantage in many cases of taking blood from a large orifice and while the patient is sitting up. In all high inflammatory diseases occurring in *robust* subjects, blood-letting is the essential remedy, other means may be used as auxiliaries and even sometimes be necessary, but our principal reliance is upon the lancet. In other words, it is the proper remedial agent in cases of pure hyperdynamia.

It may also be employed in many cases of adynamia and with benefit. If we abstract blood in the cold stage of an inter-

* Pathological Anatomy, vol. i. p. 15.

mittent fever, we take it chiefly from the larger vessels (for the tissues are nearly empty) and by so doing we shall diminish the violence of the reaction which is about to come on, that is, we prepare for the ensuing hyperdynamia; but when the adynamia is very severe it is useless to talk of taking blood, for unless we open the arteries we shall not be able to obtain it; the circulation being in a great degree arrested at the tissues.

It is in ataxia, however, where the employment of the lancet requires the greatest reserve and is attended with danger; in order to understand this, let us take a man in health and suppose him to lose a large quantity of blood, what will be the effects upon him? He will bleed until he faints, that is until he is thrown into complete adynamia, which will necessarily be followed by reaction; we shall find a bounding, febrile pulse of a peculiar kind, likened by Rush to the feel of a shattered quill; we shall have also hot skin, and probably delirium. Here is a pure case of ataxic hyperdynamia; but to relieve this condition which has been produced by the loss of blood, would any man in his senses think of taking away more? and yet in some cases it is necessary, as we shall presently show. The great danger consists in reproducing the adynamic state; if we are forced to take blood we must do it cautiously and by the application of cups and leeches. Placing the patient in an erect posture and opening the veins of his arms, is, in such cases a sovereign recipe to produce death.

We are forced sometimes to take blood in such cases on this account. The reaction which ensues may be attended with inflammation in some vital organ, as the brain, lungs, etc. We are now between two fires, we have to treat an inflammation caused by blood-letting and run the risk of killing the patient by taking away more blood, or of letting him die of the disease, which in those cases, is extremely liable to terminate in effusions. The safer plan is not to rob the system of more blood, unless we are actually forced by the urgency of the symptoms, to abstract it locally, and to employ at the same time those remedies (as prussic acid, digitalis, etc.) which have a tendency to throw the nervous system into an adynamic state; or (in meta-

physical language) to quiet the system. But we must also be on our guard, not to carry these remedies too far, for if we produce complete adynamia we shall have another reaction following it.

In all cases of ataxia whether produced by the loss of blood or by long-continued disease, or by over-stimulation as in delirium tremens; we must keep in mind the condition of the nervous system; the fatal facility with which it passes from the hyperdynamic state into adynamia, and from adynamia into hyperdynamia. Hence the benefit of opium, solitude, darkness, etc., in delirium tremens and the fatal consequences of blood-letting. Persons bled in this disease die, for the most part in the same way as those who perish immediately after surgical operations, without reaction. If they survive the first effects, the ataxic condition is increased and they die from exhaustion.

It may seem strange but it is nevertheless a fact, and one perfectly consistent with the principles laid down, that we may produce inflammation by the abstraction of blood. Take an animal and bleed him every day for a week or ten days, and he will die, probably with pneumonia attended with exhalations, or inflammation of some other viscus. First an adynamic state is produced; reaction follows; and the organ most predisposed to disease is attacked by inflammation.

In many cases of ataxia, nutritious, but at the same time easily digested diet, is clearly indicated, to supply the loss of the vital fluid which the system has suffered. Tonics, gentle exercise, rest, and fresh air, and sometimes narcotics, are also required to bring back the system to a state of health.

When ataxia supervenes after inflammatory diseases arising from the influence of poisonous agents, the treatment becomes far more delicate and difficult—most of the fatal cases of yellow fever perish in the ataxic state, and after the inflammatory symptoms have subsided. There has some change occurred in the tissues, or blood, or both, which produces a singular tendency to passive hæmorrhagies, and the hæmorrhagies increase the symptoms and the danger.

CHAPTER X.

EXPLANATION OF CERTAIN PHENOMENA UPON THE FOREGOING PRINCIPLES.

First principles endow the possessor with something of the spirit of prophecy. From a consideration of the circumstances involved in a hypothetical case, events may be predicted, that have never yet happened. The knowledge of isolated facts amounts to nothing, for, without first principles, the points of importance are unrevealed. Without the assistance of primary laws, we grope in matters of science, as the traveller does, who enters some unknown dwelling at night-fall, and stumbles about, examining with his hand, now this object, and now that, and struggles in vain to form in his mind a picture of his situation, and the bearings of things around him. These primary laws are the lights, which brought into the dark chamber illumine every thing, show all objects in their right postures, develope their relations with each other, and reflect back their natural colours.

Let us therefore take the principles we have been advocating, and see if they will not accord with certain facts in physiology, of which no satisfactory explanation has yet been given.

Sensible Organic Contractility.

It is well known that Bichat included in the evidence of this vital property of his, two very different things:—involuntary muscular contraction, and certain other phenomena, such as the contraction of the skin from cold; the subsidence of tumours after the reduction of inflammatory action, etc. We see now what this last variety of his vital property is dependent on: the distending force being removed (by the causes and in the manner already described) the tissues contract from their elasticity.

Contractility of the Arteries.

We also see through the disputes on the contractility of the arteries. The arterial tunics are themselves living tissues, and they are well supplied with nerves. The processes of nutrition, of secretion, and absorption are there going on as in other parts. Expose them to cold or similar causes, and their actions will be diminished. Nutritive action is lessened, absorption is arrested,—the arterial tunics must necessarily therefore contract from their elasticity, and the calibre of the vessels will be diminished.

This effect will be propagated more or less generally according to the intensity of the injury and other circumstances; hence it may be *general*, and we have the small thread-like pulse of adynamia.

But this phenomenon is a very different one from muscular contraction, which has been attributed to the arteries solely on the authority of experiments which would equally prove the skin to be endowed with muscular contractility.

The veins, lymphatics, and lacteals also contract when exposed to cold, when they are touched by an acid, etc., and for the same reasons.

When animals are bled to death the arteries diminish in calibre from two causes—loss in the quantity of blood con-

tained in the vessels, and the intense adynamia induced. Hence in those cases we find them at the greatest possible degree of contraction. They may afterwards expand by absorption of fluids, furnished either from the atmosphere, or formed at the commencement of decomposition. In some cases the arteries contract after death from an opposite cause, desiccation. Hence the elaborate experiments of John Hunter to prove the muscularity of the arteries are altogether inconclusive.*

Circulation in the Capillaries.

The phenomena of *blushing*, *inflammation*, the *emptiness of the arteries after death*, all prove that there exists another force in carrying on the circulation than that of the heart. That force is nutritive action; and it is the cause of all those singular motions seen by Corti, Schultz and others in the closed vesicles of the Chara Hispida, the larger Celandine and other plants. It is also the cause, and almost the sole one, of the motion and transference of the nutritive fluid in all vegetables, and in animals without heart.

We can now understand the discrepancy of microscopical observations concerning the capillary circulation. Some saw the motion of the blood accelerated when the parts were irritated; others saw it retarded; and both were correct. At first adynamia is produced, the tissues contract and the blood is driven rapidly from them. An interval ensues during which there is scarcely any motion discerned; hyperdynamia then comes on, the blood rushes rapidly to the spot, the capillaries are expanded, and the motion of the globules accelerated. But the increase of action may drive too large a quantity of blood into the parts;—the capillaries may be choked—coagulation ensue, and the movement of the blood be again retarded.

Mr. Thomson, in his Lectures,† makes use of the following

* Treatise on the Blood, etc., by John Hunter.

† Lectures on Inflammation, etc., by John Thomson, M. D.

words: "Even touching the body of the animal with the point of the finger generally occasioned a stop for an instant of time; a stop, however, which seems to depend chiefly, if not solely, on the effort which the animal makes to deliver itself from some new and unknown danger; for it was not a second time produced, when the touches of the finger were slight, or frequently repeated; nor did this stop continue when the finger was kept applied to the body, though it occasionally took place at the moment the finger was removed." The animal experimented upon was the frog.

Marshall Hall, also, in his "Essay on the circulation," remarks; that "frequently on first placing the web of a frog under the microscope, there is for some minutes no circulation. Afterwards, when the circulation is seen proceeding rapidly, it is frequently instantly arrested on pressing or even touching the animal.

"This effect appears to arise from the influence of *fear*. It ceases when the frog has been some time in its new situation."

He is right. The effects are caused by fear;—a mental emotion which even in man produces similar effects. We see the countenance turn pale;—a flow of limpid urine occurs, etc.

The change that occurs in the substance of the brain, and which accompanies the emotion, is transmitted along the nerves and affects the tissues:—hence the phenomena.

The singular and heretofore unaccountable movements observed in the globules of the blood as they traversed the capillaries, have caused several eminent physiologists to attribute a self-propelling power to the blood.* But this is obviously repellent to all our notions of matter and its actions. Spontaneity of motion belongs solely to beings possessed of volition.

The Pulse.

When we open an artery in the living body we find the blood not only gushing forth at every stroke of the heart, but also

* Müller's Physiology—translated by Baly, vol. i. p. 222.

running during the diastole. Were the arteries rigid tubes this could not occur, for the blood would pass through them at every stroke of the heart, and during the intervals between the pulsations the tubes would be empty. On the other hand, were they flaccid tubes and capable of much expansion, the force of the heart would be spent in distending them; there would be a wave progressing from the heart to the capillaries; and the synchronism of the pulse would be lost. A medium state, therefore, between perfect rigidity and flaccidity is what is required for the arteries, and which we find them possessed of. This condition depends on their middle coat, which is of the yellow fibrous, or (as it is sometimes termed) *elastic* tissue. This tissue is one sui generis, differing in physical and chemical properties from both the white fibrous and the muscular; for it is extensible and dilatable, and therefore differs from the former; and it does not contract under the influence of galvanism, and therefore differs from the muscles.

When the blood is thrown from the heart, and strikes the column already in the arteries (for they are always full) it produces two effects. It expands to a certain extent the arterial tunics; these by their elasticity react on the blood during the diastole, and by this means keep up a continual flow of blood towards the periphery until the heart strikes again, which it does by the time the contraction of the vessels has reached its greatest extent.

The second effect is that the whole column of blood from the aorta to the periphery is thrust forward *en masse*, and it is this forward rush striking our fingers which constitutes the pulse.

The arteries not being perfectly rigid tubes, the pulse cannot be exactly synchronous; but it is so nearly so, that it may pass as such.

The *number* of pulsations in a given time depends, therefore, entirely upon the action of the heart. These pulses are designated as *slow, frequent, irregular,* and *intermittent.*

The volume of the pulse depends upon the condition of the arterial tunics, which again depends on two things, viz., the quantity of blood in the system, and the condition of the tissues

into which the arteries run. Thus we may have a *small* pulse at one wrist, and a *full* pulse at the other; as in the experiment in which we dip one hand into cold, and the other into hot water.

The *time* in which the pulse leaves the fingers depends upon the condition of the tissues. In whitlow we have a *quick* pulse at the wrist on the side affected, whilst that in the other arm may be perfectly natural.

The *strength* of the pulse depends on the heart and general condition of the nervous system. In a perfectly formed case of hyperdynamic fever we have the pulse full, strong and hard; in adynamia, small and slow; in ataxia it is fluctuating, generally however soft and weak with alternations of the frequent and quick.

The rationale of all this has been given already.

Sleep of Plants.

All the world is acquainted with the phenomenon styled by Linnæus "the sleep of plants." It is common to all plants that bear leaves, though more evident in certain tribes than in others. At the rising and setting of the sun the leaves change their relative positions; a change which varies in different plants. Undoubtedly the postures they assume are determined more or less by internal structure, influenced indeed by external circumstances. For the most part they approach each other at the setting of the sun and separate at his rising. The first phenomenon is termed the sleep of plants.

As this phenomenon coincides with the rising and setting of the sun, it is natural that we should seek in the influence of light and heat the causes of it. M. De Candolle has made some experiments on this subject which I will here transcribe. "When," says he, "I exposed sensitive plants for many days together, to a strong light during the night and to darkness during the day, I saw them at first open and close their leaves without observing any fixed rule; but at the end of some days

they submitted to their new position, and opened their leaves in the evening when they were illuminated, and closed them in the morning when their night commenced.

"When I exposed these plants to a continued light, they had as usual, alternations of sleep and waking; but each of these periods was, of shorter duration than usual.

"When exposed to continued darkness, they had likewise alternations of sleep and waking, but very irregularly."*

He also showed that the opinion of Murtel, who attributed the phenomena to the agency of heat, was untenable. We must, therefore, refer them chiefly to the influence of light.

Heat, indeed, may and does sometimes produce similar effects by robbing the leaves of their moisture faster than it can be supplied by the roots. At noon of a hot summer's day, we see the leaves and flowers drooping; and some delicate flowers only expand after sunset, when the leaves are folded in sleep.

The influence of light on the nutritive actions of vegetables is well known. Without its presence the combination of water and carbon will not take place, the plant is deprived of its green matter, and its taste and other properties are entirely changed. Light, therefore, is necessary to those actions which go on in the leaves of a plant;—when present they go on rapidly and with energy; when removed, they go on less rapidly and languish. Now we have abundantly shown the consequences of diminishing the intensity of nutritive action: less fluid is absorbed into the tissues and they contract by their elasticity;—hence the sleep and waking of plants. The phenomena may undoubtedly be modified by other causes, such as hygrometic state of the atmosphere, climate, season and many other circumstances.

But if we read attentively the experiments of De Candolle we shall see that there are other causes engaged besides the influence of light. The plants continued to open and close their leaves both in constant darkness and continued light. Moreover in some plants such as the *oxalis incarnata* and the *oxalis*

* Physiologie Végétale, Lib. iv. chap. vi.

stricta, he could neither by continued darkness or continued light modify their sleep in any way. The conclusion to which he comes is plausible and perhaps true. "I think," says he, "that from these facts we may conclude that the movements of sleep and waking in plants, are connected with a disposition towards periodic motion in the vegetable, but which is essentially put in activity by the stimulating influence of light, which acts with a different intensity on different vegetables, so that the same dose of light produces different effects on different species."*

But by this explanation we have evidently only changed the difficulty, for the nature and causes of this periodic motion itself become problems for us to solve. The regular return of day and night, of the seasons, and perhaps of the lunar revolutions—in short, a frequent repetition of the same causes and effects, seem to impress upon all living beings, a series of internal movements which follow in regular succession, and which endure even when causes intervene calculated to arrest or pervert them. We have thousands of instances of this in animal life, and we denote the facts, and our ignorance of their causes by the word, *habit.* Why is it that we awake from sleep at a certain hour? How comes it that almost without volition—certainly without premeditation, the musician runs so accurately over the chords of his instrument? These and a thousand similar questions may be asked, but where shall we find the answers?

Movements of the Sensitivæ, etc.

It is well known that certain plants, as the *sensitive mimosa, dionæa muscipula,* etc., close their leaves when mechanically irritated. The extent to which the plant is affected will depend on the violence of the impression; sometimes but a few leaflets are affected; at other times, the whole plant may be so. The motion seems to be produced by a contraction of the cellular

* Op. cit.

tissue at the articulations, either of the leaflet, or the common leaf stalk, or of this last on the stalk.

The circumstances which modify these movements are as follows. The plant is more sensible to the shock, the more vigorous it is; and the movements are more prompt in a higher than a lower temperature. By frequent repetition the plant seems to get exhausted, until finally no more movements will take place until after a long repose, it regains its original vigour.

Any sort of body, conductor or non-conductor of electricity, will produce these emotions. It will occur in light or darkness, in the air or in water, in a dry or moist atmosphere;—no difference being observed, provided the region of the plant and the temperature be the same.

Desfontaines showed by experiment that these plants were capable of accustoming themselves to the mechanical irritation. If placed in a carriage, they close their leaves as soon as the carriage is put in motion, but after a while will unfold them again, though the motion of the carriage still continue. If the vehicle be stopped and again put in motion, the sensitive will again close its leaves.

Chemical agents, such as nitric or sulphuric acids, produce the same effects, but much more rapidly than mechanical shocks. The effects also last much longer.

Finally, these plants may be poisoned by any of the narcotics. When sprinkled with water containing five per cent., of prussic acid, the leaflets close at once, and after a quarter of an hour or so open again; but their sensibility is diminished and is not regained until the lapse of several hours.

In all these cases we see a striking analogy to the effects produced on the nervous system, by similar means.

But these plants possess no nerves; how then shall we explain the phenomena?

I remarked in another place that I did not believe the nervous substance the only one in nature capable of taking on isomeric changes in consequence of mechanical impressions. All

substances, which fulfilled the conditions there specified, must necessarily be subject to similar effects from the same causes.

I suggest, therefore, that the contraction produced in the sensitive plant, occurs in the same way as it does in cases of adynamia in animals. An isomeric change is produced in the tissue itself; a change of relation with the nutritive fluid ensues, nutritive action is diminished; less nutritive fluid is absorbed into the tissues; and they contract by their elasticity.

On Ciliary motion.

Throughout the whole group of the invertebrate animals, and in parts of those higher in the scale, there is a species of motion performed by what are called, *cilia*. These organs are fibrillæ of a minuteness so great, as not to be distinguished except with the aid of the most powerful microscope. They are exceedingly numerous, and are found on the tentacula and other parts of the radiata, and on the serous and mucous tissues of the higher animals.

They are in constant play and appear to give a particular definite direction to the fluids in which they are immersed;—a circumstance which led to their discovery.

The principal facts connected with ciliary motion are as follows:

It continues long after death. It is not connected with volition, because it continues in the tentacula after they are severed from the rest of the body. In the higher animals, it ceases much sooner than in the lower;—in fact, the lower the animal in the scale of life, the longer the continuance of ciliary motion. The shock of a Leyden jar does not put a stop to it; but when the galvanic current is strong enough to produce disorganization of the tissue, the action ceases. Light has no influence upon it; but that of heat is considerable. It is not at all affected in animals killed by the most powerful narcotics; nor indeed, by the immediate application of them. It is therefore altogether independent of the nervous system.

A contractile tissue at the base of the cilia, it has been thought, is the cause of this motion. If this be true, the contraction must resemble that of the heart;—that is, it must depend not upon external stimuli, but upon internal actions which we do not well understand. But how is it possible to conceive of motion in a determinate direction produced in a liquid by the play of such organs as the cilia. The impulse given in the descent of the cilium, must unquestionably be lost in its ascent, if the two movements be done in equal times, and which seems to be the case.

I will not undertake to account for this obscure phenomenon, but I suspect the explanation should be reversed,—namely, tha the motion of the liquid is the *cause*, not the *effect* of the ciliary motion. It must be remembered that there are certain internal movements (those, namely, which attend on nutritive actions) going on in the parts which bear the cilia, vary even in the cilia themselves. I suspect, therefore, that the motion of the liquid is produced by reciprocal action with the living parts, and that this motion affects the cilia.

On the Motions of the Hedysarum Gyrans, and of the Heart.

The movements of the Hedysarum Gyrans is thus described by De Candolle. "Its leaves are composed of three leaflets, two lateral, linear, oblong; and another without a fellow, removed from the former two, much larger, and of an oval-oblong form. The two lateral leaflets are in almost constant motion, which is executed like that performed by the second hand of a watch, that is by a quick sudden jerk—one of them rises about fifty degrees above the level of the leaf-stalk, whilst the other descends in about the same proportion. When the first commences to descend, the other begins to rise, and in this way they are kept in a constant oscillatory movement. The single leaflet moves also by sometimes inclining itself to the right, sometimes to the left,—a motion which we may compare to a demi-pronation,—and a demi-respiration. The motion of this leaflet is constant, but very slow, if we compare it with that of the lateral leaflets.

This singular mechanism lasts during the life of the plant, continues day and night, during both dry and hot weather, and appears only to be modified by the temperature of the air, and the general health of the plant. When the weather is hot and moist at the same time, the plant is most vigorous and the movements most rapid, especially in the lateral leaflets. It is said that in India these leaflets have been seen to execute sixty little jerks in a minute, but it is rare to observe such rapid movements in our green-houses. When the plant is in a languishing condition, several minutes sometimes passes between the jerk of the lateral leaflets."*

The resemblance of this periodic rythmic action, to that of the heart must strike every one.

The first motion observed in the embryo of the vertebrate animals is that of the heart. Its action is rythmic, constant, unremitting and endures the whole course of life. These traits distinguish it from all other muscles.

Legallois proved that affections of the nervous substance reacted powerfully on the heart. By crushing the spinal marrow he put a stop at once to the heart's action, and reasoning *post hoc ergo propter hoc,* he imagined the principle of the heart's activity resided in the spinal marrow. Wilson Philip showed the falsity of this notion. It is now known that the heart of many of the inferior animals will continue to act a long time after being removed from the body. It is therefore not the stimulus of blood acting either directly on the muscle, or indirectly on them through the medium of the nerves, that causes the alternate contraction of ventricle and auricle. Nor is the atmospheric air, nor any other stimulus the cause of its motion, since these movements occur as well *in vacuo,* as in any other situation.

These periodic movements of the heart and of the hedysarum gyrans, I regard as pertaining to the same class. They are independent of any extraneous stimulus; though stimuli acting on the organism may interfere with, or even arrest them. They

* Physiologie Veg. Vol. II. p. 869.

seem to be the results of a peculiar nutritive action going on in the organs. Hence they are indissolubly connected with the organization: change that organization and the motion stops.

This view of the subject receives confirmation from the fact that the action of the heart is much more easily affected in the higher animals than in those lower in the scale—more easily affected in the warm blooded, than in the cold blooded. The heart of a frog continues beating for hours after removal from the body, whilst that of a rabbit or sheep ceases its action almost instantly. The organic compounds of the inferior animals are of a more fixed character than those of the higher, less complex in chemical constitution, and therefore retain their *vitality* or original condition much longer after death. We know moreover, that even in the higher animals nutritive action does not, in many cases, cease immediately with what is termed death.

Muscular Motion.

Muscles are excited to contraction, either by impressions made directly upon them, or upon the nerves running into them. The nerves of the voluntary muscles come from the anterior column of the spinal marrow; those of the involuntary muscles are chiefly supplied in the higher classes of the vertebrata, by the trisplanchnic system. In the lower classes of the vertebrata, the trisplanchnic disappears in a great measure and is replaced by the pneumogastric.

Galvanism, mechanical and chemical stimuli, all excite contractions; but there is some difference in the results, according to the manner in which the stimuli are applied. For instance, an incandescent substance, as the flame of a taper, caustic alkalies, etc., excite contractions when applied directly to the nerve; but all the narcotics, alcohol, muriate of ammonia, bichloride of mercury, etc., do not have this effect when applied to the nerve, they must be applied directly on the muscular fibre.

The muscles thus put in motion are said to *contract;* but they really do not do so;—that is, there is no condensation of their

substance. What the fibres lose in one direction, they make up in others. The experiments of Barzellotti, Thayer, and others favour this.* Muscular contraction is, therefore, a different phenomenon from the contraction of the skin and other tissues, which occurs in adynamia.

During contraction the cohesive force of the muscle is immensely increased.

All chemical and mechanical agents, capable of interfering with the chemical constitution or the organization of a muscle, destroy its irritability. Muscular irritability, therefore, is a property depending on these two conditions. The question whether the nerves must always be affected prior to the muscle, seems to be an idle one, for the two are so connected, that no contrivance can be invented by which one alone may be experimented on.

As when the muscles contract, there occurs no condensation of their substance, it is evident that the contraction must result from a new arrangement of their particles. This is brought about by the primary change in the nerve, radiated to the muscle. In all solid bodies, their molecules are kept together by cohesion, and these molecules, in different bodies take different arrangements. Hence crystallization, elasticity and porosity. It is also evident that when an elastic substance (such as gum elastic) is bent, extended, etc., its particles are displaced and roll upon each other. When the foreign force is removed, the force of cohesion brings the particles to their former relative position. An operation, the very reverse, appears to occur in muscular contraction. The foreign force (the molecular chemical change in the nervous matter) displaces the particles, but increases their cohesion instead of tending to diminish it. But this force is still a foreign one, so that the effect will cease with its removal. When the condition of the nervous substance is, therefore, altered for another, the muscle necessarily relaxes and returns to its original condition.

The change in the nervous matter which results in bringing

* See Müller's Physiology, part iv. p. 886.

about muscular contraction, seems to be one *sui generis.* In the first place, it can occur (at least for the voluntary muscles) only in one set of nerves—the anterior spinal. In the next place, it may or may not, accompany adynamia and hyperdynamia. In some cases of adynamia, as in collapse of cholera, we have cramps, spasms, and so on; and in hyperdynamia, we may have twitchings, convulsions, and similar affections; but in a great many other cases, we have no involuntary muscular movements. And yet as the whole system is affected the muscles must suffer in common with the rest of the tissues. In ataxia, the disposition of the nervous system to react on the muscles is greatly increased; hence tremors, spasms, convulsions, subsultus tendinum, from the slightest causes.

Lesions of nutritive action in the spinal cord will of course more or less be radiated to the muscles. From this cause proceed tetanus, chorea, clonic spasm, catalepsy, and similar diseases. This morbid action is not necessarily connected with inflammation.

Certain effects result from the contraction of the muscles, to which attention must be paid, because they point out the nature of the change undergone. The first is that of exhaustion;—a state much sooner induced in the voluntary than the involuntary muscles. To produce exhaustion we have evidence that a chemical change occurs in the muscle. For instance, cut two muscles from an animal recently killed; galvanize one, and let the other alone. The one galvanized will lose its irritability much sooner than the other, and it will putrefy much sooner. Again, brutes that are run to death, as the stag and other wild animals, putrefy much sooner than when killed on the spot by firearms. Further, exercise is absolutely necessary for the nutrition of the muscles. If the nerves be divided in a limb, so that it be entirely paralyzed, both nerves and muscles dwindle away and lose their properties. But it must not be supposed from this that the nutrition of the muscle is dependent on some substance or substances derived from the brain—many facts disprove this. They dwindle away because those excitations, those constant changes of relation with the nutritive fluid,—the proper condi-

tion in which they are fitted to exist, no longer occur. But we have touched on this subject in another place.

Again the more fixed the chemical elements which compose the muscle, the less numerous and the less delicately balanced their affinities, the longer will muscular irritability endure. Reptiles preserve their irritability much longer than the mammalia; and these longer than birds; an order, which seems commensurate with the quantity of oxygen consumed in respiration; and therefore, with the complexity of the blood, the evolution of heat, and the intensity of nutritive actions in those three classes.

All these facts point out, that in every occurrence of. muscular contraction, a chemical change accompanies it, which in the end may be manifested by marked results.

Animal Electricity.

The electric organs of the *gymnotus electricus,* the *torpedo,* etc., though differing in some minor particulars, appear all to agree in certain essentials. They are composed of a bundle of prisms united together by investing membranes. Each prism is divided transversely by a multitude of thin lamella apparently of fibrous tissue, running parallel to each other and thus dividing off the prism into a number of little cells, which contain a gelatinous semi-fluid. Into these organs a number of nerves of a large size enter, together with a large quantity of small blood-vessels. The nerves come chiefly from the vagus.

The animal when touched with the hand, or a good conductor held in the hand, produces a shock similar to that given by a Leyden jar; and there can be no doubt, that it is caused by electricity, since almost all the effects produced by that fluid are produced by these animals. To feel the shock, it is but necessary to touch the animal on any portion of its body.

The discharge is voluntary, but unaccompanied with muscular motion, and is dependent on the integrity of the nerves; for when they are divided, the power of effecting it ceases. Nar-

cotics produce death in the animal, attended with convulsions and strong discharges. After the animal is quite dead, and the discharges have ceased, they may be renewed for a time by irritation of the brain or spinal marrow. By repeating the discharges often, the animal becomes exhausted, shocks become more and more feeble, and finally cease altogether; but after hours of repose, the organs regain their pristine vigour.

It is obvious that most of these facts are analogous to others connected with muscular motion. In truth, the two phenomena are dependent on the same causes;—change in the chemical condition of the organs, effected by a primary change in the nervous substance. That electricity is developed during chemical change, has been abundantly proved by Becquerel, De la Rive, and Pouillet. It is therefore but necessary to change the chemical condition of the organs, surcharged with electricity, to affect all surrounding bodies, capable of conducting the fluid.

But how came these organs thus charged? The electric fluid accumulates doubtlessly during nutritive action; and its accumulation, like the power of contracting in muscles, is dependent upon a particular condition of the organs. Hence, when this condition is changed, the fluid is set free; and hence, too, the complete exhaustion of the animal, when the shocks are often repeated, and the necessity of repose to recruit its loss.

The quantity of electricity thus emitted is immense. "It is doubtful," says Mr. Faraday, "whether any common electrical machine has as yet been able to supply electricity sufficient in a reasonable time to cause true electro-chemical decomposition of water, yet the current from the torpedo has done it. The same high proportion is shown by the magnetic effects."*

Loss of Sight, etc., on division of the fifth pair of Nerves.

In a former chapter I showed that changes in the condition of a nervous substance might be propagated in opposite direc-

* Exp. Researches in Electricity.

tions; if we wound the trunk of a nerve, the change therein occurring, is sent, both to the brain and to the organs with which that nerve is connected, or (in the language of anatomists) which that nerve supplies. Now, sensation, like all the other functions of the nervous system, depends on a certain condition of the nervous substance. If the condition be but slightly disturbed, we shall have morbid sensations;—if much, none at all. The instantaneous loss of sight, smelling and hearing, which occurred in the experiments of Majendie, is, therefore, owing to this cause. By dividing the fifth pair within the cranium, he affected every one of these organs of sense with instantaneous adynamia; and hence did not limit, as he supposed, the injury to the fifth pair, but, in reality, affected in a secondary way the nervous substance of the special senses; for it must be plain, that the tissues of the eye, ear, and nostrils, could not undergo such a change in their condition, and leave at the same time the nervous matter of the retina, etc., unaffected. These results, then, are far from proving (as Majendie thought) the fifth pair to be the nerve of all the special senses.

Effects of dividing the Pneumogastric Nerves.

When the pneumogastric nerves are divided, death ensues more or less rapidly. Sometimes the animal perishes on the spot; others live for a few hours; some, but very rarely, survive more than two days. This, when both nerves are divided: when one only is cut across, the animal may survive many months. The causes of death are different. 1st. The animal may perish on the spot from suffocation,—according to Majendie, when we operate above the recurrent nerves, we paralyze those muscles which dilate the glottis, and the animal thus perishes for want of air. 2ndly, From secretion into the bronchiæ and air-vesicles of the lungs; thereby preventing the access of air to the blood. 3rdly, From inflammation. This, however, rarely happens except when only one nerve is divided, for the animal, if it escape the first cause of death, falls, in general, a victim to the second.

With the first cause, we have nothing to do at present. The second, however, for many reasons, claims our attention.

The reader may consult, for the effects produced by this operation, the Works of W. Philip, of Brachet, of Majendie, and numerous other authors. From the last-named author I make the ensuing extract.

"Respiration is at once constrained, the movements of inspiration are longer, with less interval between them, and the animal appears to give them a particular attention. The movements of locomotion are seldom taken, and they evidently induce fatigue;—often indeed the animal continues perfectly motionless. Nevertheless, the formation of arterial blood is not prevented at first; but very soon, the second day for instance, the difficulty of respiration increases, and the efforts at inspiration become greater and greater. The arterial blood begins to lose its vermillion hue, its colour is darker, and its temperature is lowered. At last, all the symptoms are exacerbated. Respiration is effected only with the aid of all the inspiratory forces; the arterial blood is of a dark red, and almost like venous blood; the arteries contain but little of it; coldness of the body ensues, and the animal soon perishes.

"Upon opening the chest, we find the bronchial cells, the bronchia, and often the trachea itself, filled with a frothy fluid which is sometimes bloody. The tissue of the lung is engorged and voluminous. The branches, and even the trunk of the pulmonary artery, are strongly distended with deep coloured, almost black, blood. Considerable effusions of serosity—sometimes of blood itself, are found in the parenchyma of the lungs. On the other hand, experiments have shown that in proportion as these symptoms show themselves, the animals consume less and less oxygen, and form less and less carbonic acid."

The cause of death is obvious;—a lesion of secretion, or rather an *exhalation* of venous fluids into the air-vesicles of the lungs—thereby preventing mechanically the access of air to the blood. This exhalation is caused by the adynamia produced in the lungs by the wounds made on the pneumogastric nerves; and is of the same character with the flow of limpid urine from

fear; of tears, from grief; of the diarrhœa, profuse clammy and cold perspiration of cholera, and other adynamic affections.

The stomach is also affected in the same way. Hence the arrest of the digestive process, which depends on gastric juice, a secretion caused by *irritation.*

The heart does not seem to be much affected by this operation, probably, because the branches of the pneumogastric nerve which runs into it, are much smaller and finer in number than those which supply the lungs and stomach; and probably, also, because they only enter the heart indirectly, that is, after having joined the sympathetic in the cardiac plexus. It is owing to this unequal affection of the three organs that the fatal exhalation takes place; for in cases of general adynamia, when the heart suffers as much as the other organs, these exhalations rarely occur.

W. Philip* asserted in one of his papers to the Royal Society, that, if after division of these nerves, the extremities be placed in contact or nearly so, digestion is not so much impaired as when a part of the nerve is excised. Breschet, Vavasseur and Milne Edwards† repeated together these experiments of W. Philip, and they conclude that, simple division of these nerves does not entirely arrest digestion; and that digestion is more impaired by taking out a piece of the pneumogastric nerve than by simply dividing it.

Majendie‡ on the other hand declares that he has never seen any difference in the effects produced by simply dividing the nerve or by taking out a piece of it.

Perhaps there is some little difference in the effects produced by the two methods; and for an obvious reason. The effect produced will be proportioned to the injury; so that if we wound the nerve twice instead of once, the after lesion will be greater.

Majendie refers the effects produced on the stomach, not to

* Exp. Inquiry.

† Archives Gen. de Médécine, Août, 1823.

‡ Précis. Elem

the immediate division of the nerves, but to the impairment of the respiratory function. The stomach, in other words, is only affected secondarily. He rests his opinion upon an experiment in which he divided the pneumogastric on the œsophagus, after they had given off their pulmonary branches. Digestion, he asserts, was not arrested—the substances introduced into the stomach were chymified.

Breschet, Vavasseur and Edwards varied the experiment by tying or cutting off the œsophagus just above the cardiac orifice, and they found that digestion was impaired.

It seems to me that this subject can be disposed of without calling in question the accuracy of either of the parties. The effects produced by lesions of the nervous substance will vary greatly in different individuals, according to temperament, age, sex, health, disease, and a number of other circumstances. Hence, Majendie, operating perhaps, on a robust subject, did not witness the effects so well pronounced as he had been accustomed to do. But that division of the pneumogastric nerves must influence primarily the organic actions of the stomach, seems to me a necessary consequence of the laws of the nervous system. At the same time, it must be granted that these effects may be more or less increased by the cause Majendie points out.

The reader has doubtless foreseen what opinion W. Philip intended to support by asserting that when the divided ends of the nerves were placed in contact, digestion and respiration were less impaired, than if a piece was taken out. It was made to confirm the theory of a nervous fluid passing from the brain to the lungs. When the ends of the divided nerve were separated, the passage of the fluid was arrested: when placed in contact it still flowed onwards, though in diminished quantity. Making this experiment, then, with this view of the subject, he could scarcely fail to find what he looked for;—particularly when he turned his attention to the stomach. All lesions of the nervous substance will vary in some respects according to circumstances,—according to age, sex, temperament, etc. And we are told expressly by Majendie, "that a division of these

nerves in the neck does not always interrupt chymification. The experiments which have just been made in Paris by M. M. Breschet, Vavasseur and M. Edwards, have induced the authors to believe, that the digestive process is merely enfeebled."* Such being the case it is no wonder that W. Philip found just what he was in search of,—especially as he ardently desired it.

The nervous fluid, according to him, is identical with galvanism. Hence he set about making experiments to prove that galvanism would supply the place of nervous influence. He applied one galvanic pole to the thoracic extremity of the divided nerve, and the other to the epigastrium; and to his delight and surprise, the dyspnœa and other symptoms were relieved; and after death, it was found that the aliment introduced into the stomach just before the operation, was converted into chyme. These results so convinced him of the truth of his theory, that he forgot to take notice of a most important fact, which nevertheless he has recorded as if by accident, in many of his experiments. It is, that all the animals which were galvanized died in spite of all his efforts, *much sooner than those he left to themselves after having divided the nerves.*

It is not difficult to explain the results obtained by W. Philip from the application of galvanism. In adynamia, as every physician knows, there is a call for stimulus. The vital actions are all diminished, and it is, therefore, necessary in many cases to change the condition of the nervous substance by the agency of substances, which, experience points out to us, are calculated to effect that object. This is accomplished for the pneumogastric nerves by galvanism. The nervous substance of the lungs and stomach passes from the primary lesion of innervation towards the secondary irritation. Hence the exhaling tissue of the lungs is converted into an absorbing one; the fluid already exhaled is taken up, and respiration is free. In the stomach the nervous substance is put in such a condition, that the ingesta produce the usual irritation there; gastric juice is secreted; and the aliment is converted into chyme.

* Précis Elem.

But though these effects are produced for a time, yet with nature we cannot thus violently interfere with impunity. In all nervous phenomena, as I have repeatedly inculcated, the nervous substance undergoes a change in its condition, its chemical relations with the nutritive fluid are altered. And no doubt in these passages from one condition to another, its chemical *constitution* does not remain unchanged. We see this truth evidenced, if not in simple phenomena, yet invariably after frequent repetition. In sensation, in muscular motion, in short, in all nervous functions, exhaustion comes on sooner or later. Hence it is absolutely requisite that we suspend these actions for a while in sleep, in order that the nervous substance be recomposed, and thereby fitted for organic actions. What may be the peculiar play of chemical actions which thus occurs in the nervous substance, we do not know; for it is a subject apparently beyond the reach of investigation. We are led, however, by our reason and by strong analogies, where the eye cannot follow.

W. Philip, then, produced a change in the nervous substance by the application of galvanism, more favourable than its previous condition for the maintenance of vital actions. But the misfortune was, that having produced this condition, he could not maintain it. As long as the violent stimulant was applied, were serious changes going on in the constitution of the nervous substance. Hence it passed rapidly through irritation into exhaustion and death. Instead of prolonging life, he shortened it.

The effects produced on the lungs and stomach by dividing the pneumogastric nerves, are not confined (except as to intensity) to that operation. In depressing mental emotions, the sigh so laboriously and frequently uttered is but a symptom of the same state of things. The loss of appetite on the reception of bad news is familiar to every one:—

> Read o'er this;
> ——— And then to breakfast, with
> What appetite you have.

The same thing occurs when severe wounds are inflicted on

any part of the body: sickness, vomiting, etc., being the most common symptoms attending such injuries. Had W. Philip not been blinded by theory he could have scarcely failed to perceive this truth; for he himself produced the very same impairment of digestion by wounding the spinal marrow at the lumbar vertebræ, as he did by dividing the pneumogastric nerves.

In pneumonia the cause of the morbid action is generally the inspiration of cold air under peculiar circumstances. The nervous substance of the lungs is first thrown into a state of adynamia; but in robust or young individuals this condition seldom lasts long enough, or is sufficiently severe, to cause the fatal exhalation. But it is very different when it occurs in aged, broken down constitutions. Then we have that fatal and horrible disease called *Peripneumonia Notha*, in which death occurs in the same manner as when the pneumogastric nerves are divided. To treat this disease correctly we should, therefore, stimulate.

I was so convinced of the correctness of the above views, that I had determined to perform an experiment, in which only one of the nerves was to be divided. In such a case the animal would live by the action of one lung. At the end of eight or ten days I intended to kill it, expecting to find in the lung supplied by the nerve operated on, unequivocal evidence of inflammatory action. But I have since found such authority for the truth of my suspicions, that to perform the experiment would have been cruel and useless.

Majendie says: "in some dogs I cut the eighth pair on one side only; three months afterwards, I cut that of the opposite side: the animals died three or four days after this last section. On opening the body, I found the lung supplied by the nerve first operated on, in such a condition that it could not have served for respiration."*

Mr. Swan, relating the post-mortem appearances of a dog that had died the *fifth* day after ligature of the par vagum; says:

* Précis. Elem.

"the pleura was inflamed and smeared with purulent matter. The right lung was hepatized, but the left was so in a very slight degree. The inner portion of the pericardium was smeared with a thick glutinous matter, nearly the same as the pleura. The mucous membrane of the larynx and trachea, was vascular in a slight degree, and presented some muco-purulent matter with a substance resembling coagulable lymph."*

Traces of pre-existing inflammation are, however, not always found after division of every one of the nerves. Cases of this kind are mentioned by Majendie himself, and also by Dr. Reid.† The inflammation in these cases must have been slight, and therefore, passed off as in common pneumonia, by solution.

Function of the Spleen.

I shall pass over the minute anatomy of the spleen, concerning which so much has been said, as it is not of much importance to our present purpose. There are two points, however, which it is necessary to bear in mind. The spleen is by far the most dilatable, the least resisting of all the organs in the body; and at the same time it is highly elastic. Easily expanded to a size sometimes treble that of its natural dimensions, it will contract gradually down to its former state, whenever the distending force is removed, and this, without any lesion of structure or inflammatory action occurring in the organ.

Now what is the force that expands the spleen? In all cases it is the blood, propelled by arterial tension. "Take," says Majendie, "the three dimensions of a dog's spleen—the abdomen having been previously opened; inject into the veins a pint of blood from another dog;—you will see the spleen gradually enlarge and acquire, at the end of the injection, a magnitude greater by one third or one half, than it was before.

"On the other hand, having measured the spleen, bleed the ani-

* Med. Chirur. Review, April, 1834.

† Experimental Investigation, etc.

mal *ad deliquium;* and you will see the spleen gradually contract as the blood runs off."*

The spleen will, therefore, expand whenever arterial tension occurs; and we now explain how that takes place.

The spleen swells and becomes painful whenever we make any unusually violent exertion, particulary if this be prolonged as in running, dancing, inordinate laughter, etc. Arterial tension must therefore occur in these cases; and it occurs in a very obvious way. The action of the muscles on the veins, determines the flow of more blood to the heart in a given time, than when we are at rest. The action of the heart is increased in frequency; more blood, in a given time, is thrown into the lungs; hence, the necessity of frequent respiratory efforts. But what is particularly to be attended to, is, that all extraordinary muscular efforts are attended with an expiratory movement, which is much longer continued than that of inspiration. This, any one can convince himself of in a moment by experiment. Now the effects of inspiration upon the blood in the great vessels, are to accelerate the current in the veins, and retard it in the arteries. Those of expiration are exactly the reverse—accelerating it in the arteries, and retarding it in the veins,—indeed, as has been proved by experiment, causing a reflux, and distention of their coats in all the veins unfurnished with valves. In expiration, therefore, particularly if it be forced or long-continued (as in violent laughter, which consists in a rapid succession of expiratory efforts,) the blood, propelled down the arteries, and retarded in the veins, will inevitably congest in the tissues and capillary vessels. Hence, the explanation of many phenomena, such as redness of the face, hemorrhage from the nose, headach, increase of perspiration and so forth, in consequence of violent exertions. Among the other organs, the spleen of course will not remain unaffected; hence, the pain we feel in all such cases; and which arises from the sudden and rapid distention of the organ.

* Précis. Elem.

This is one way in which distention of the spleen occurs: it enlarges, however, under circumstances very different.

In adynamia, as has been said over and over again, the blood is driven from the tissues generally and thrown upon the large blood vessels. In many cases, even the capillaries are quite empty. This large quantity of blood thus suddenly thrown upon the vascular system, must give rise to arterial tension, which will continue until relieved by the extraordinary exhalations which accompany severe cases of adynamia.

Now it is a remarkable fact that the spleen, in adynamia, instead of subsiding like the other organs, expands. This must be familiar to every medical man who has taken pains to observe at all. What is more common than enlargement of the spleen in ague and fever? and whoever will take the trouble can soon satisfy himself that this enlargement takes place in the cold stage and partly goes off in the hot. The great size to which the spleen arrives in many of these cases, is owing to the frequent repetition of the attack;—it is at last dilated beyond its power of elastic retraction. Moreover, the best possible way of curing one of these enlarged spleens, is to administer quinine and nutritious diet;—the *modus operandi* of which is perfectly clear. By these means we establish energetic nutritive action throughout the system. We divert into the shrivelled or dropsical pallid tissues, the arterial blood. They elicit it, take it from the arteries, the tension of which is thus taken off, and the spleen is permitted to contract to its natural dimensions.

In corroboration of these views I will mention an experiment of Mr. Hodgkin. Having opened a rabbit and measured its spleen, he exposed it to intense cold; the spleen rapidly enlarged under his eyes.*

It now remains for me to show what would be the effects if no such organs existed: I have already alluded to the exhalations which accompany adynamia. These exhalations must not be confounded with the secretions, for they are very diffe-

* See notes appended to Dr. W. Edwards' work "On the Influence of Physical Agents," etc.

rent;—the first being nothing more than the watery portion of the blood, with perhaps a little albumen and some salts;—the second being distinct substances elaborated from the blood. These exhalations are caused by the action of the heart and the arterial tension. The *vis à tergo* continually acting, drives the more watery portion of the blood through the tissues upon the surfaces or into the cavities. This cannot occur in health, and still less in fever, for then the tissues exert an attractive force over the blood: they control, attract, repel it, and perform with it all those operations which constitute nutritive action. But in the present case, *i. e.*, adynamia, the relations of the solids and nutritive fluid are altered; nutritive action is almost annihilated; in fact, the tissues are in a state approaching that of a corpse, into which, if we inject warm water, it will pass just like these exhalations into the cavities.

In truth, whenever arterial tension occurs, in adynamia or in any other state, exhalation into some of the cavities is very apt to occur. This is made evident by an experiment of Magendie, who by injecting the veins of a dog with water, produced copious exhalations into the lungs, peritoneum and other parts.*

Now suppose this arterial tension to occur when the heart has lost none of its force, as in running, violent laughter, etc., and there was no provision to relieve the vessels. We should be continually exposed to the most fatal casualties, for should the exhalation take place upon the brain or the lungs, death would be the inevitable consequence.

Dupuytren, as is well known, excised the spleen of forty dogs. Twenty of them survived the operation and did well. Several he afterwards killed and examined;—he found no effects whatever which he could attribute to the absence of the spleen.

According to professor Coleman, animals that have lost their spleens, grow fat and indolent.

I think we now see the meaning of this. The spleen is not an organ essentially necessary to life; it must be regarded as an organ vicarious in its exercise; and of no use whatever ex-

* Précis. Elem.

cept under the circumstances which call upon it to perform its office, when it becomes of the greatest importance.

The spleen, therefore, is an organ attached to the circulatory apparatus, and its function is to relieve arterial tension whenever it occurs.

For this purpose it is admirably fitted by its organization, being so easily dilated, yet possessing high elasticity, so that it can return readily to its natural size, when the tension is removed; and being also so constructed, that the blood which passes into it, is never beyond the control of the solids, as it would be in a cavity like a sack, and therefore subject to coagulation.

The following observations of Kaltenbrunner bear upon this subject. He remarks, "that during the passage from life to death, there occurs a very singular change in the smallest vessels of the spleen during life, the distribution of the vessels in the spleen, is analogous to that of the liver; but when death takes place, there occur changes which remind us of what occurs in the inferior animals. All the smaller arteries, veins, and capillaries become difluent, and the blood escapes into the parenchyma, where we find it in red patches. The larger arteries and veins, however, retain their blood."*

It is this flow of blood, then, *extra vasis*, that causes the tumefaction of the spleen. The flow, doubtless, occurs from the pressure caused by the congestion in the larger vessels. In both adynamia and *articulo mortis*, it is an exhalation.

* Journ. de Physiologie, par Majendie, tom. viii. p. 87.

CHAPTER XI.

APPLICATION TO PATHOLOGY.

The three conditions of the nervous system which have been pointed out, namely; adynamia, hyperdynamia, and ataxia, are not necessarily connected with morbid action: we may observe the same rotation of conditions, the same passage of one into another, in health, as well as in disease, though to be sure, not so distinctly marked. The condition of the body in sleep is characterized by all these symptoms proper to adynamia;—by the slow and measured respiration; by the diminished frequency and volume of the pulse; by the diminution of temperature; by the diminished reaction—by the increased exhalations; and above all, by the absence of sensorial phenomena. All these signs show a condition of the nervous substance in which the operations of life are performed with less energy—a circumstance which forms the grand characteristic of adynamia. Indeed if we follow out a parallel between the state of wakefulness and that of irritation; and between sleep and adynamia, we will be struck with the many points in which they reciprocally coincide.

The nervous substance passes from sleep into wakefulness, as it passes from adynamia into irritation; and as irritation within certain limits passes into ataxia and thence back into health; so does the excitation we experience during the day, pass gra-

dually into fatigue, weariness, and exhaustion, and thence into sleep. It is the action of excitants on the nervous substance, existing in a condition fit for the pressure, that keeps up these many phenomena which constitute the excitation of the day; just as in irritation, slight stimuli cause increase of pain and of organic action. In sleep, these slighter excitants have but little effect; they must be increased in quantity and intensity to cause a change in the nervous substance. In adynamia, it is the same.

Again, we have seen that narcotics produce adynamia, and narcotics, we all know, equally produce sleep.

Cold again produces adynamia and likewise sleep. An insurmountable tendency to sleep, is one of the most alarming symptoms in persons exposed to intense cold. And conversely, persons during sleep evolve less heat than when awake. Hybernating animals, it is well known, pass the winter in a state of profound slumber; and Dr. Edwards,* in his experiments, was able to produce this state of torpor, by merely reducing the temperature of the animals, the subjects of his experiments. In this condition, all the actions of life are reduced; the breathings are at long intervals; the pulse slow and scarcely perceptible; the secretions all diminished; and the slumber profound. That all these effects are dependent on the same condition of the nervous substance, I think there can scarcely be a doubt; particularly when we call to mind, that in every sensation the nervous substance undergoes a change, which, transmitted to the sensorium, is a *sine quâ non* to the sensation; and that these changes are absolutely incompatible with the equable and diminished nutritive actions which occur during hybernation.

Finally, adynamia is marked by diminished quantity of blood in the tissues; irritation by an increased quantity. Now we are told by Blumenbach that he was an eye-witness to a phenomenon which occurs in the brain when a person passes from sleep to wakefulness. In a man whose skull had been injured, and a part of it removed, a tide of blood was seen to rush into

* On the Influence of Physical Agents, etc.

the brain and distend it when he awakened out of sleep. On the other hand, when he fell asleep, the brain was seen to shrink and subside.*

This observation shows that the seat of sleep is the brain. The rest of the nervous system seems to be affected secondarily. Hence it is that a man may sleep in a fever;—the brain and the rest of the nervous system existing in opposite conditions. In irritation of the brain, sleep is impossible.

In consequence of the power possessed by the spinal cord of radiating its affections, arise what are termed *secondary* affections. They may either be adynamic or hyperdynamic; but may be best studied in the latter character. The number, character, and effects of these secondary affections, will depend on several circumstances; to wit:

1. On the condition of the nervous system.
2. On the intensity of the primary affection.
3. On the natural organization of certain parts.
4. On the condition of the organs at the time the primary affections occur.
5. On the quantity of blood in the system.
6. On the character of the morbific cause.
7. On idiosyncrasy—that is, individual peculiarity not well understood.

Like the rest of the tissues, the nervous is changing its constitution from birth until death. In early life, it is more readily impressed;—that is, a change of condition is more readily induced than in adult life, and this last more readily than in old age; and young animals much more readily recover from the effects produced upon them, than those of more advanced years. This is well demonstrated by the experiments of Dr. W. Edwards, who found that a degree of cold, in which the parent animal retained its natural heat, quickly caused a reduction of temperature in the young of several warm blooded animals. So, also, the adult resists the influence of cold much longer than the young; but when the cold has affected its ner-

* Elements of Physiology, Am. Edit., p. 226.

vous system, it is with difficulty recovered. The young animal, on the other hand, though more easily affected, recovers much more rapidly.

There are many other variations of the nervous system—differences with respect to sex, race, temperament, habits, and many other circumstances; but the chief points of importance, so far as connected with our present object, have been already brought before the reader in the chapter on ataxia.

With regard to the intensity of the primary affection, we have but a word to say; since it must be obvious, *ceteris paribus*, that the intensity of the secondary affection, must be proportioned to that of the primary.

The organs naturally take precedence of each other in their dispositions towards secondary affections. Andral has arranged them in the following order: the brain and spinal cord, that portion of the alimentary canal situated below the diaphragm, the lungs, the heart, and lastly, the skin.* This arrangement is founded on observation; yet it is not difficult to find reasons for the facts; for those tissues which are most prone to the secondary affection, are precisely those which are most easily affected primarily. The greater or less facility of undergoing isomeric change is what determines the precedence. The stomach and small intestines are lined with a mucous coat of extreme delicacy, and in great abundance, and this tissue is one of the most porous in the whole body. It is also supplied with large quantity of arterial blood, and numerous nerves. A slight change in the condition will therefore be made apparent on the instant. In hyperdynamia the blood will be drawn into the tissue and become engorged there, producing in the organ a condition which in its turn will be the cause of other effects. Hence, it

* Perhaps the alimentary canal should be placed first in this list. Out of 2338 cases of intermittent fever treated by Thaillot, in 1834–5 at Bona, the intestinal canal was affected in 1078 instances; alone, in 343; with the brain, in 686, with the lungs, in 31; and with the brain and lungs, in 13 cases. In 25 cases, the spleen alone was diseased; and in one case the peritoneum alone. The brain was affected alone in 466 cases; the spinal cord in one; the lungs alone in 103 cases, and the pluera alone in five.—*See British and Foreign Med. Review, July*, 1839.

is, that when the body has experienced an injury resulting in a general affection, the stomach is sure to exhibit its secondary effects. The other mucous tissues, such as those of the tongue, eye, bronchia, etc., are liable to the same consequences, though not to the same extent.

The same observations are applicable to the brain, lungs and other viscera.

This great liability of the stomach to be affected secondarily, has given rise to an opinion that most fevers have their origin in a primary affection of that organ. This is by no means true: yet a particular attention to this organ, and to the intestines, brain, and lungs, is one of the most important duties of a physician; for the secondary affections to which they are subject from their natural organization, frequently give rise to a train of symptoms, which demand all the resources of medical art to overcome. The primary affection may become, in these cases, of little importance;—it being the secondary that is doing the great mischief, exacerbating the primary, calling other organs into the vortex of disease, exhausting the system, perverting the operations of life, and threatening immediate death by disorganization or effusion. This is particularly the case in diseases arising from poisonous agents;—but on this point, we shall have more to say hereafter.

The true test of the value of general principles is their application to practical purposes. Let us therefore, give this subject a little more attention; and choosing the stomach for the purpose of illustration, let us consider the course of treatment we are called on to pursue in cases of high fever.

The stomach is one of those organs from which nervous affections are most readily transmitted, and in which they are most frequently developed. I must be understood; I mean that the stomach is an organ which is affected by agents that would scarcely produce a visible effect if applied on most of the other parts of the body; and that being thus affected, the change is transmitted to the spinal cord (the centre of the nervous system) and thence, to the rest of the body. And again, that any change in the condition of the nervous centre, will be evidenced

in the stomach sooner than in most of the other organs, provided there be no other organs predisposed to disease.

This doctrine is not the offspring of fancy; it is the result of rigid observation. The proofs of its being true, are manifold. What a sudden effect is produced on the whole system by the introduction of any of the caustic poisons, as arsenic, corrosive sublimate, and so on, which act upon the mucous tissue! How sudden the loss of appetite on the reception of bad news! Vomiting from the prick of a couching needle, or from injuries received on any part of the body, is a common occurrence. Again, how numerous and important are the sympathies of this organ in disease? There is no general disorder, and very few local affections of any intensity, in which the stomach does not give evidence of being more or less affected.

But it is almost superfluous to multiply instances of the gastric sympathies. We can hardly open our eyes without seeing them. The nausea occurring in the sight of a disgusting object; vomiting from blows on the head or testicles, from wounds, from inflammation of the kidneys and other organs, are only a few selected from an immense number.

Such then being the relations of the stomach with the rest of the system; it is at once plain how proper it is to direct our remedial agents to this organ. But on the other hand, equally urgent are the inculcations of caution and nice discrimination in administering them. For if instead of bringing back the organ to a healthy condition, our medicines should have an opposite tendency, we increase at the same moment the morbid state of the stomach and the primary disease; for the affection of the stomach will be transmitted to the spinal cord, and thence to the rest of the body. To illustrate these positions, suppose a man to receive a compound fracture of the leg. In a day or two his tongue becomes red and dry; showing a change in the condition of the mucous membrane. If wine or calomel (except as a cathartic) be now given him, the already morbid state of the stomach is increased, its affection is transmitted to the spinal cord, and thence to the rest of the body. We should therefore add to the primary disease and lessen the chances of recovery.

But if instead of such means, blood-letting, cooling drinks and similar remedies were administered, we would benefit the leg at the same time that we lessened the morbid condition of the stomach; for a change in that organ necessarily brings on one in the nervous centre, and consequently in the wounded limb.

From this view of the subject we see at once how absurd is the doctrine of those theorists, who contend for active purging, as a means of depletion in febrile diseases of high action. The mucous membrane of the stomach already in a morbid condition, is acted on by these irritants, and what is the consequence? An increase of diseased actions throughout the whole system; and if there be an organ already inflamed, an increase of action in that organ. I am very far from objecting to the employment of cathartics in fevers of a high grade, but it is with other views that I would administer them. There is generally a mass of ingesta in the alimentary canal, which from the suspension of the digestive process, becomes altered in its chemical constitution and is thus a source of constant irritation. It may, moreover, become so vitiated as to form fluids, which being absorbed act as poisons on the economy. By the early administration of a purgative, we remove this irritating matter and thus benefit the patient. But the *direct* effects of the purgative have not been at all in our favour; for it has added somewhat to the morbid state of the mucous membranes. But as it carries with it, irritating matter out of the body, a balance is struck in our favour, and we gain more than we lose. But when this is accomplished, we have done all the good we can do by the administration of cathartics, and to continue the use of them any longer is both absurd and mischievous.

This doctrine of using cathartic medicines as a means of depletion, is one of the most pernicious in medical history. I say *one* of the most pernicious, for there is another which ought to be placed on the pinnacle of absurdity. I here refer to that doctrine which teaches us to administer mercurials in febrile diseases of high action, with a view to restore the secretions; but principally (as it is said) to emulge the liver. But before these things can reach this all important *sine quà non*—the liver

(which autopsy shows us to be as little liable to disease as any organ in the body, and with which disease may take more liberty, perhaps, without producing a general affection, than any other) they must act upon the stomach and duodenum;—organs already perhaps in a state of inflammation, or in such a condition, that a very slight cause will bring it on. Now before our approbation can be given to such practice, those who contend for it, should prove that calomel and blue-mass are excellent restoratives when applied to an inflamed part on the surface of the body;—to a simple incised wound, for instance. Moreover to restore the secretions of an organ suffering from inflammation, we must lessen the inward action. The lancet, cups, leeches, cold, and so on, are the proper means to attain this end;—not mercurials, which, when they do any good, seem to do so only when the fever is subsiding or has left the patient.

But whilst some have thus turned their eyes from these obvious sympathies of the stomach and fixed them with astonishing perverseness on the liver, as the organ most liable to secondary affections, there are other theorists who have gone just as far in error on the other side. They seem determined to regard some favoured portion of natural phenomena, and be blind to all others. They regard the stomach as the organ suffering most in all general affections, and in every case without exception. This is not true; for frequently it is the lungs or brain, or spinal cord, on which the violence of the disease settles most. We must in these cases, turn our attention to those organs and use every means in our power to relieve them. We hear repeatedly from these men, that the stomach is the centre of the sympathies. This shows an utter ignorance of what sympathy is. If there be any centre to which nervous affections are transmitted, and from which they depart, the spinal cord must be regarded as such, for thither, as is proved by experiment, all impressions are transmitted. Nervous affections are never propagated from one organ to another in a direct manner. The uterus does not transmit its affections immediately to the stomach, nor the stomach to the uterus; but the impression is sent from the organ

first affected, to the spinal cord, and thence to the rest of the body. All, therefore, that can be said of the stomach, is, what has been said already;—namely; that it is one of those organs from which a change of condition is most readily propagated, and in which it is most frequently developed.

"There are," says Andral, "certain organs never affected with secondary hyperæmia, unless some one particular organ has been the seat of the primary affection. The tongue, for instance, although like all other parts of the body, liable to attacks of idiopathic hyperæmia, is never thus affected sympathetically, except when the stomach is previously affected."* There are undoubtedly many sympathies of this kind. Chronic inflammation of the uterus almost always affects the brain; inflammation of the kidneys affects the testicles and stomach. It is singular that when these organs thus disposed to secondary inflammations, are *primarily* affected, they do not particularly affect those organs, with which they seem to be so intimately connected. Inflammation of the brain does not particularly affect the uterus; nor does inflammation of the stomach or testicles bring on inflammation of the kidneys. These facts, as likewise, the particular sympathies themselves, are inexplicable; just as in the case of particular volitions affecting certain muscles, and these only;—facts, which we do not understand, since the change and movements in the nervous substance are molecular and entirely concealed from us.

If when a local inflammation sets in, there be any of the organs already diseased or just recovering from an attack, they will be most liable to the secondary affection. "Hence it is, that we observe as secondary phenomena, palpitations, dyspnœa, hæmoptysis, gastric symptoms, hæmaturia, or menorrhagia; according as the heart, lungs, stomach, kidneys, or uterus, are, or have been diseased, and thus rendered more susceptible of secondary hyperæmia."†

* Anat. Pathol., tom. i.

† Andral, Anat. Pathol., tom. i.

The character and effects of these secondary affections will differ again according to the quantity of blood in the system at the moment of attack. It has already been shown that in high fever the tissues draw the blood into them with a force stronger than they do in health; therefore according to the quantity of blood in the system, will more or fewer organs be affected with secondary inflammations. Hence in gastritis we sometimes see the skin injected, at other times, pale. The brain and its membranes are also sometimes found inflamed, and at other times exsanguineous. "These pathological observations," says the author, I have already quoted more than once, "afford satisfactory explanations of several morbid phenomena. Thus, for instance, they enable us to understand how the delirium, convulsions, and other nervous disorders, so frequently supervening during attacks of acute gastro-enteritis, are in some cases produced by repetition in the cerebro-spinal system, of the congestion originally formed in the mucous membrane of the intestinal canal; whilst in others, the same symptoms depend on the exsanguineous state of the nervous system, resulting from the circumstance of the blood accumulating in the organ originally congested."*

Individuals differ greatly in respect to the quantity of blood the body contains, even though they be of the same size and in a perfect state of health. Those of that diathesis called the plethoric, have the greatest share, and hence they are more liable than all others to sudden attacks of inflammatory diseases, such as apoplexy, pneumonia, etc.

It frequently happens when there is not too much blood in the system, that the establishment of a secondary inflammation entirely relieves the primary, by drawing off the blood towards the seat of the secondary affection. This fact has led to the employment of blisters, sinapisms, etc., for the relief of inflammatory diseases:—by establishing an inflammation on the skin, we relieve an internal organ. But they should be employed with great caution; for if the system requires a loss of blood, or

* Andral, Anat. Pathol., tom. i.

if it be in an ataxic condition, that is, in what we term an irritable state, they will infallibly do mischief. In the first case by joining with the primary disease to produce fever with all its consequences; and in the second, by increasing a condition of the system already dangerous. In *all* cases in which blisters are employed for the relief of inflammatory affections, they do good only when their action is merely *local;*—if they affect the system they do injury. Similar remarks may be made with regard to the use of warm baths. If the fever be high, the stimulus of heat will increase it, and exacerbate all the symptoms; and hence we frequently find patients who have been thus treated, with dry hot skin and dry tongue, five minutes after leaving the bath, instead of being in a free perspiration as was anticipated.

Secondary affections both as regards their number and their character, differ again according to the morbific agent producing the primary affection. The causes of disease are of three kinds; moral, mechanical, and chemical. Of the first it is not my intention to speak. As regards the mechanical causes, it is evident, that their influence will be determined (*cæteris paribus*) by the violence of the primary lesion, and by the different organs and tissues on which they act. But as regards the third class of morbific agents, it is very different. For leaving out of view all modifying circumstances, and considering the action of these agents as upon individuals in all respects similarly situated, it will be found that the number, character, course, and effects of the inflammations they produce, will depend upon the particular substance introduced into the system. The poison of measles will produce a specific effect; that of scarlatina, another; that of small-pox, another; that of yellow fever, a fourth, etc. In fact, every substance, which can take on the liquid state, is thereby enabled to enter the current of the circulation, whence it will be thrown upon the tissues, and there have its due influence;—increasing or diminishing the actions of nutrition; but in either case, perverting them. Many of these substances are necessary for the maintenance of life; many produce but trivial effects which soon pass away; but

others cause results far more powerful and permanent, and to these we give the name of *poisons*.

I have supposed two individuals, similarly situated in all respects, to be acted upon by the same morbific agent. But, in fact, though we may make this supposition in order to establish a general principle, it will not do to act upon it in practice. For we scarcely ever meet with two individuals thus situated. Persons differ, that is, the tissues differ, according to age, sex, temperament, habits, race, idiosyncrasy, condition of the system at the time of attack, and many other circumstances. All these will have their influence in modifying the effects produced by the morbific agent. Hence the innumerable shades of difference to be observed in cases of measles, small-pox, yellow fever, etc. In teaching a science we are obliged to classify,—to arrange phenomena into groups, and to treat of *specific* differences; but in practice, we must remember that we are not called upon to treat *species* and *genera* (which are merely creatures of the mind) but particular tissues in which perverted action is going on;—that though we may find the general characters by which we name the disease, yet we shall also find a number of particular symptoms, which owe their origin to contingent circumstances. All *specific* treatment of diseases,—that is, all treatment which administers the same remedies to all cases of diseases which bear the same name, is preposterous and murderous. General physiological principles applied to the particular case before us, must be our guides in the treatment, as the particular symptoms must guide us to a diagnosis. Every practitioner of experience knows that it is frequently necessary to treat two cases bearing the same name, by exactly opposite means.

Poisons are of various kinds and act very differently upon the organization. Some of them, as arsenic and corrosive sublimate, destroy life by combining directly with the tissues. Others pass through the system unchanged and are found in the excretions, but they disturb the organic action in their transit, and therefore must act as catalytics;—probably the narcotics act in this way, but the especial *modus operandi* is utterly unknown.

Other substances, again, suffer a chemical change after entering the body, and are found in the excretions in different forms, from those in which they entered; thus the acetates, tartrates and citrates of the alkalies are converted into carbonates which, are found in the urine. Some poisons reproduce themselves, as yeast is reproduced when in contact with sugar and gluten: these poisons are called *contagious.* During the putrefaction of animal and vegetable substances, another species of poisons is generated, called *miasms;*—they differ from contagious in not being reproduced; and are probably volatile oils, or decomposing organic substances held in solution by ammonia. The production of miasms depends upon peculiar circumstances, for putrefaction under ordinary circumstances, does not generate miasm. The peculiar conditions necessary for the generation of miasms, are not well understood.

The action of poisons on the economy is one of the most interesting in physiology; but it would be out of place here to take up the subject *in extenso.* The reader is referred to the work of Christison, and particularly to Leibig's excellent work on Organic Chemistry.

When any of the narcotic poisons are introduced into the stomach, or come in contact with an abraded surface, they are absorbed into the circulation, thrown upon the different tissues and organs, among others, the spinal cord and brain; and in these latter organs produce narcosis, and the other symptoms peculiar to the particular poison. They also produce a local affection on the part to which they are applied, and thus render the tissues unfit for the organic actions. When applied to a nerve they destroy its function, but only at the spot where applied, for the nerve, above and below, transmits its impressions if it be irritated. From this it is obvious that the *chemical* changes, produced in the nervous substance by the poison, is never transmitted to the spinal cord; the *isomeric* one of adynamia is that only transmitted. These propositions are susceptible of proof by experiment.*

* See Müller's Physiology, vol. i. p. 246 and 627.

When putrefied pus, brain, muscle, and so on, are applied to fresh wounds, sickness, vomiting, and great debility immediately ensue, attended with an adynamic state of the system, which is soon followed by reaction, and usually, death, with peculiar characteristics, follows in the course of three or four days.

Gaspard and Majendie produced the same effects by injecting putrid animal matter directly into the veins of animals. The effects are precisely those which characterize yellow fever.*

It is obvious that, in usual cases, the path of the miasm into the circulation, is through the delicate membrane which lines the air-vesicles of the lungs.

In cases of disease arising from poisonous agents, some most important points, with regard to their pathology, must be attended to. A poison taken into the circulation, is thrown upon the tissues indifferently, and wherever thus thrown, will necessarily interfere with the nutritive process, and pervert the functions of the part. Thus the heart of a frog will beat for hours after having been removed from the body; but the injection of a few drops of infusion of tobacco under the skin, will in a few minutes totally arrest its action—never to return. The same effect will occur if it be touched with the infusion after having been removed from the body. The poison, therefore, acts directly on the tissues of the heart.

But as the poison wanders wherever the blood is thrown, some portion will find its way to the axis of the nervous system,—that is, the spinal cord, and interfere with the nutritive process therein going on; and as that organ is the common centre of all the nerves, it will radiate its affections to every molecule in the body. Hence the sudden adynamia, and the quick reaction in diseases arising from miasm or contagion.

These diseases, therefore, differ in important respects from those arising from mechanical lesions. In cases of fever from burns or wounds, the irritation is transmitted to the spinal cord, and thence to the rest of the body; but the general affection in

* Journal de Physiologie, tom. ii. and iv. Leçons sur les phénomenes de la vie, par Majendie.

diseases of the class we are now considering, has *two* sources;—one, in the tissues on which the poison may happen to alight; and the other, in the direct action of the poison on the cord itself.

It must also be remembered that miasms and contagions are chemical agents acting on the tissues, and tending to produce decomposition thereof.

For these reasons it is, that, in diseases created by contagions or miasms, the fever bears no ratio whatever to the intensity of the primary inflammation. In vain, at the commencement of the attack, shall we search for any local inflammation to which we can attribute the violent general affection. None in truth exists. The inflammation of the stomach, bowels, brain, etc., found in *post-mortem* examinations, are the *consequences* not the causes of the fever. As well might we attribute the fever to the injected eyes or skin, which supervene only on the third or fourth day, as to inflammation of the stomach or any other organ. The cause of the high fever is the existence of a poison interfering with the process of nutrition in the tissues generally, and especially, in the nervous substance of the spinal cord.

From these causes, also, it is, that we have so many secondary inflammations formed in diseases of this kind. Hence, too, the rapid disorganization of the tissues, the morbid changes produced in the blood, the passive hæmorrhages, suppression of the secretions, and other symptoms, which attend these diseases.

To conclude this chapter, I shall merely mention that idiosyncrasy or individual peculiarity has its influence in modifying secondary affections, just as well as on those which are primary. Some particular organ, as the brain, lungs, stomach, etc., shows in some instances a predisposition towards secondary affections: a predisposition attributable only to individual peculiarity of organization.

APPENDIX, NO. I.

NO. I.

AN EXAMINATION

OF

THE ELECTRIC THEORY OF NERVOUS ACTION.

As the analogies between the effects produced by nervous action and galvanism are very striking; and as many eminent writers have supported the theory of their identity, it is perhaps fitting that we take an impartial scrutiny of that theory and give the reasons why it must be rejected.

This theory is based on the following facts.

1. If steel or iron needles be introduced into any part of a living animal, (as is done in the operation of acupuncture) and then be connected with Schweigger's galvanometer, the instrument gives the usual signs of a development of electricity.

2. Prevost and Dumas, have proved in their experiments, that the galvanometer is affected when the muscles contract.

3. If a muscle together with its nerve be taken from an animal recently killed, and the nerve be galvanized, the muscle will contract.

4. Wilson Philip, has shown in his experiments, that the dyspnœa and other symptoms, which follow the division of the pneumo-gastric nerves, are relieved (at least partially and for a time) by the application of galvanism. So, also, digestion, which is impaired, and sometimes totally arrested after this operation, goes on if galvanism be applied to the lower portion of the divided nerves. The author operated by covering the

lower end of the divided nerves with tin foil, and placing a silver plate over the stomach of the animal, the tin and silver were then connected with the opposite extremities of the galvanic pile.

5. The analogy between the chemical effects of galvanism, and the control which the nerves seem to exert over the chemical actions of nutrition and secretion, and over the phenomenon of absorption.

6. The existence of certain animals which possess an apparatus by means of which they discharge electrical shocks at pleasure.

The pith of this doctrine, is contained in the following remarks of Wilson Philip. "We have reason to believe that the nervous influence is the galvanic fluid collected by the brain and spinal marrow, and sent along the nerves; galvanism being, not only of all artificial means of exciting the muscles, that which seems best adapted to this purpose, but capable of both forming the secreted fluid, and causing an evolution of caloric from the blood, after the nervous influence is withdrawn."*

We shall first show that the facts above mentioned do not warrant the inference drawn from them; and then proceed to demonstrate from other facts that the hypothesis *cannot* be true.

It must be kept in mind, that according to the most careful and accurate experiments of modern philosophers, the galvanic fluid is only developed during chemical action; in other words, that the theory of Wollaston, has entirely overthrown that of Volta. It must also be remembered that if a complete circle be formed of heterogeneous substances, which are conductors of electricity, and which can act chemically upon each other, or upon which the oxygen of the atmosphere can act, or upon which any fluid, in contact with them can act; we shall have a development of galvanic fluid. Hence, if we place a piece of zinc, and another of copper in a tumbler of water, and they are brought in contact either immediately, or by the intervention of

* Experimental Inquiry, chap. xi.

metallic wires, galvanism is excited and the current will be from the zinc, across the water to the copper, and along the wires back to the zinc. So, also, if we take a piece of copper in one hand, and place it in contact with a piece of zinc in the other, we shall have a circle formed, and the galvanic current will be from the zinc to the copper, up the arm, across the breast and down the other arm into the zinc again. The intensity of the current will be in direct ratio to the chemical actions going on between the zinc, oxygen of the air, or of the moisture which is held in the air by solution ; so that if the experiment in either form be made with substances not oxydizable, such as gold and platinum, no current whatever is excited.

Now to apply these principles to the case of acupuncture. When two steel needles are introduced into the animal body, they are plunged into parts bathed in blood, (a highly chemical compound) and a chemical action ensues between the metal and the liquid. So that when the needles are connected with the wires of Schweigger's galvanometer, we have nothing more nor less than a simple voltaic circle formed; and under such circumstances, it would be very strange, indeed, if the magnetic needle of the galvanometer was not affected. The proof of this is that when the needles are withdrawn from the flesh, they are found to have lost their metallic brilliancy, and to present every evidence of their surfaces having undergone chemical alteration. On the contrary if we use *platinum* needles as was done by Pouillet* and Pearson,† the galvanometer is not affected for the blood does not act chemically upon that metal. "I have" says the last named author, "put the poles of the galvanometer in communication with the anterior and posterior portions of the spinal marrow (the functions of which are so different) in young cats, dogs and rabbits. I have repeated this experiment in different parts of the spinal marrow, after having divided the roots of the nerves. Having made incisions into the ring formed by the cerebellum and pons varolii, I applied both on the surface

* Journal de Physiologie, par Magendie, tom. v.
† Ibid, tom. x.

and plunged deep into the nervous substance, the little blades of platinum which terminate the threads of the instrument. I have stuck these threads into different parts, in many of the larger nerves, hoping thus to put them in relation with opposite currents. I have repeated these experiments after having injected tincture of nux vomica into the abdomen; in order that I might excite muscular contraction at pleasure. Analogous attempts have been made on eels and frogs, which live long under the influence of strychnine. *Never have I perceived a certain indication of electricity*, and yet I have used galvanometers of extreme delicacy.

Pouillet has performed the same experiments with the same results. The development of electricity obtained in acupuncture, therefore, proves nothing. Were the steel wires thrust into a turnip or a potato the very same effects would be produced.

"Let" says Prevost and Dumas "two similar platina wires be fitted to the ends of the branches of the galvanometers, let one of them be plunged in the muscles of the frog, and the nerves of the animal be touched with the other heated to redness. The contraction will be strong and the deviation of the needle very sensible. Both these phenomena will be produced but with less intensity if the heated metal be applied to the muscles."*

Now in all this what do we see but the formation of a voltaic circle, composed of muscles, nerves, platinum and the copper wire of the galvanometer. If a chemical action ensues at the point where the platina wire touches the nerve electricity will be developed and evinced by the needle. But we have already shown that platinum undergoes no chemical action with the nervous substance;—it must therefore occur in the nervous substance itself. And what better way of effecting a chemical change in that highly compound body than by applying the platinum *heated to redness.* If a chemical change occur in the substance of the nerve, two effects will be produced, a development of electricity and contraction of the muscles; but it cannot be said

* See Appendix to Edwards' sur l'influence des agens physiques, etc.

that the former is the cause of the latter, any more than we can say that the oxidation of zinc in the galvanic battery is owing to the electricity developed. Moreover "two portions of the same metal of different temperatures, develope electricity as well as portions of different metals, there would, therefore, necessarily be a deviation of the needle produced in the experiment here described."*

A stream of electricity sent across the trunk of a nerve will cause the muscles it supplies to contract: but so also will the muscles contract if the nerve in a living animal be touched with a piece of glass, or any other non-conducting body. It must be evident that this, and all similar facts, only prove that electricity is one of the many causes capable of acting on the muscles through the medium of the nerves.

As dyspnœa and impairment of digestion occur when the pneumogastric nerves are divided; and as partial relief is obtained by the application of galvanism; W. Philip infers two things: the interruption of the nervous current, and the identity of nervous influence and galvanism. But the facts may be read in another way. Thus: the dyspnœa and indigestion are caused by paralysis (adynamia) of the lungs and stomach induced by wounding the nerves in the neck. In all such cases stimulants are required and the good effects of galvanism are produced in its character of a stimulant. In another place we have already taken notice of an experiment of W. Philip, by which he attempts to prove that if after the nerves are merely divided, the ends be left a line apart, the nervous influence is transmitted from the upper to the lower portion. It is sufficient here to say that there is no proof whatever of there being any *current* of any kind in the nerves, to or from the brain.

As for the fifth argument, namely, the analogy between the chemical powers of galvanism, and the control the nerves exert over nutrition, absorption and secretion; it is a sufficient reply to say that all these actions occur in beings (as vegetables) which have no nervous system. Here we have effects ascribed to galvanism, produced without the existence of nerves. But it

* Müller, Physiology, trans. vol. i. p. 638.

may be said that galvanism pervades all parts of a vegetable. Well;—and why should it not pervade all parts of an animal, whose material is the better conductor? To perform the aforementioned actions, where is the necessity of separate organs for the conveyance of galvanism in the one case, that does not exist in the other?

With regard to electrical fishes, I have already given a description of them, and of the mode in which I conceive the phenomena to occur, suffice it now to say that an explication on the principles of the present theory is utterly impossible. For we must suppose that the galvanic fluid has accumulated in the electric organs in the same way that it accumulates in a Leyden jar. Now this cannot be, for the inside and outside of a Leyden jar, are, and *must be* separated by a non-conducting substance; but there is no non-conducting substance, (excepting fat and oil) in a living animal; being, as all moist animal membranes are, not only conductors, but good conductors. Again, the current which gives the shock from a Leyden jar, passes directly from the positive to the negative side by the shortest route; but from these animals the shock is extended far around for several yards, and in all directions, through all the conducting substances that happen to be in contact with them. "The electric fishes have been adduced by some physiologists in support of the hypothesis of the electric action of nerves: but the very fact of the existence in these fishes, of organs constituted after the manner of galvanic piles, is unfavourable to the theory, for if electricity were an active principle of the nerves, the fishes would require only conductors and not a special galvanic apparatus."*

Furthermore we have as good reason to maintain that nervous influence is identical with light or heat, as relying upon such facts, to maintain that it is identical with galvanism; for the firefly is provided with analogous organs, from which by an effort of volition† it emits light, and all the higher animals are

* Müller, vol. i. p. 639. Trans. by Baly.

† Triveranus, however, attributes these emissions of light to the inspiration of air. In the irrespirable gases the phosphorescence ceases or at least diminishes. —*Müller*, vol. i. p. 92.

so constructed as to maintain a temperature in their bodies of 98° F. even in an atmosphere as low as zero.

We shall now give some other facts which we regard as direct proofs against the electric hypothesis.

Galvanism, like all other stimulants when applied continually, so far from keeping up the phenomena of life, produces death. From an animal recently killed, excise two muscles with their respective nerves attached; lay one of them by, and galvanize the other with a battery of feeble power. After a while the contractions become less and less strong, and finally cease altogether; nor can they be ever renewed again. When this is done, galvanize the other, and it will contract as violently as if just removed from the body. Here then we see that one of the muscles *left to itself* has retained its contractility, whilst the other having been galvanized, has lost it.

The same thing occurred to W. Philip in his experiments on the pneumogastric nerves; and the fact was always mentioned by the author, though he was blind to its importance. In one experiment,* he placed two dogs, as far as possible, under the same circumstances, and in each of them divided the pneumogastric nerves. One of the animals was then left to itself:—the other was galvanized. The galvanized dog died in $2\frac{1}{4}$ hours after the division of the nerves, "the other (to use the author's own words) was still alive at the end of four hours after the nerves had been divided, but so weak that it could not stand nor move itself from the place where it lay on its side. *It was killed at this time by a blow on the occiput.*"

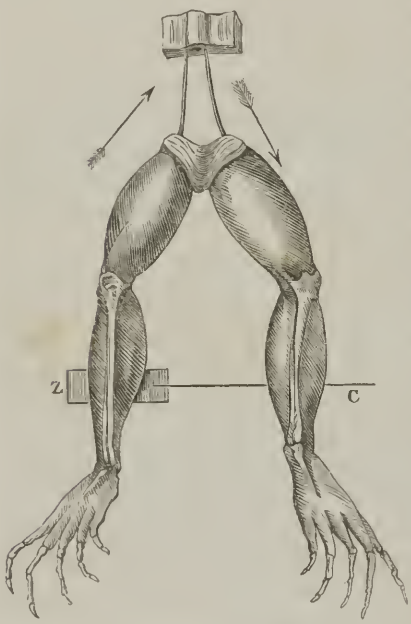
The neurilema is not a non-conductor of electricity; the muscles and other organs into which the nerves plunge, are good conductors; therefore the galvanic fluid cannot be retained in nerves. To prove this, we shall cite an experiment of Pearson,† "Let a frog be prepared (as indicated in fig. 1) by isolating completely the lumbar nerves, which, however, must be left in union, either through the medium of the spinal marrow, or which

* Op. cit. exp. 49.

† Op. cit.

amounts to the same thing, by putting their extremities in contact. If we place a piece of zinc (z) under one leg, electricity will be produced by the chemical action of the moist flesh upon the metal which will become negative, whilst the muscles become positive. If we now connect the other leg with the zinc, by means of a metal not easily oxydated, such as copper, the circuit will be closed, and there will be a current in the direction indicated by the arrows.

Fig. 1.

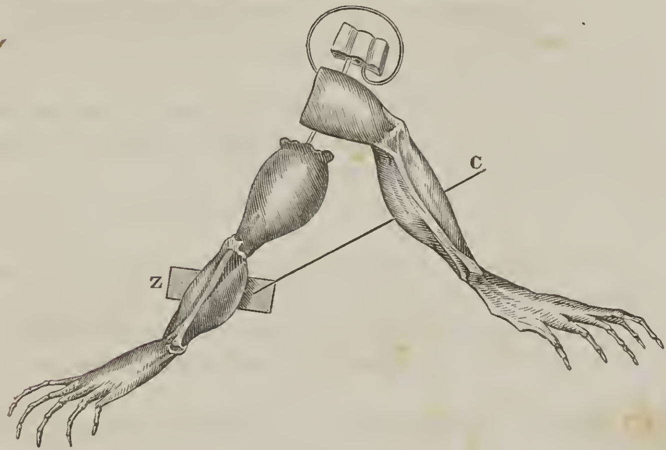


"In galvanic experiments without a pile, we obtain with difficulty a few oscillatory movements, when the current traverses the muscles or passes through the nervous filaments exceedingly small; whilst on the other hand, we have violent convulsions if the electric current passes through a portion of the principal nerve. This circumstance shows us the route taken by the current. In the experiment which I have just related, it passes by the nerve; therefore, the contractions are powerful. But if we place the two thighs in contact, we have nothing more than fibrillary movements—evidently caused by the current passing through the muscles which offer a shorter route.

"Let now one of the thighs be placed on the nerve of the other, as is shown in figure 2, the current instead of following the nerve passes through the neurilema to enter the muscles of the thigh (*c*) which will evince fibrillary movements only; whilst the other will be violently agitated."

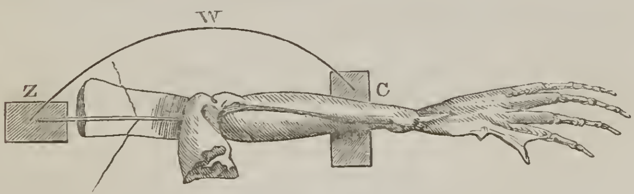
An electric current will pass through the nerve after it is tied but the nervous influence will not pass under such conditions. Lay

Fig. 2.



bare the sciatic nerve of a frog; divide it in order to prevent interference on the part of the animal; and then galvanize the lower extremity by taking a piece of zinc in one hand, and a piece of copper in the other, and putting them in contact with the nerve resting on the zinc. Violent contractions will be produced in the muscles of the limb. Tye the nerve below the point galvanized, and the contractions cease instantly.

Fig. 3.



Again, remove in another frog the entire limb, and after isolating the sciatic nerve place it on the zinc (*z*) and the leg on copper (*c*.) as shown in figure 3. On closing the circle by a

metallic wire (w) we shall have strong contractions. *A ligature will not prevent them;* "which," says Pearson, "is plain enough, as the neurilema, to which the nerve is reduced at the ligature, is almost as good a conductor as the nervous pulp," moreover the nerves are good conductors after death when neither electricity nor any other agent will excite contraction in the muscles to which they lead.

Finally upon such a theory as this what possible explanation can be given of the sudden and extraordinary effects produced by certain poisons such as prussic acid, etc.*

Upon the whole, therefore, we must agree with Pearson,† that,

1. "The existence of electric currents in the nerves, is an hypothesis contradicted by experiment.

2. "The action of electric currents on the nerves should be put in the same category with chemical and mechanical stimuli.

3. "Metals are infinitely better conductors of electricity than the nerves.

4. "The nerves are not better conductors than the muscles: their powers of conduction do not change when they are disorganized by mechanical violence.

5. The neurilema is incapable of isolating the most feeble electric currents which we can produce in galvanic experiments; so that if the muscle intervene, the current will pass from the nerve into it."‡

* Narcotics (as laudanum) instantly render the nerve powerless even though it be galvanized.—*See Christison, p.* 3.

† Op. cit.

‡ The reader will do well to consult Müller's Physiology on this subject, vol. i. p., 633, chapter on "the active principle of the nerves." The arrangements adduced are similar to those above.

APPENDIX, NO. II.

NO. II.

ON LIFE.

Physiology is the science of life;* but if there be such a science, it must contain general principles applicable to all living beings:—to the simplest plant as well as to the most highly organized animal.

We say that the mushroom is endowed with life, and that man is also so endowed:—in what do beings so dissimilar agree?

By observing living beings attentively and comparing the phenomena they present with those of brute matter, we discover two important facts. First, we observe that all without exception, appropriate to themselves, by some means or other, certain substances external to their bodies, which substances we term *aliment*. Secondly, we observe that if this aliment be withheld there ensues, at a period more or less remote in different cases, a total cessation of all the phenomena of life. We

* "Physiology," according to present usage, treats of the laws, organs, functions, etc., of life; "Physics," not so. Now, quære: the etymological import of the two words being the same, is the difference in their application accidental and arbitrary, or a hidden irony at the assumption on which the division is grounded? *Φυσις ανευ ζωης, ανευ λογȣ*, or *λογος περι φυσεως μη ζυης εϛι λογος αλογος*.—*Coleridge*.

know besides that the aliment always enters the system in a fluid state, and as the supply of aliment may be considered as constant during life, and as there occurs no accumulation of this fluid in the living being, it follows, as a matter of necessity, that this fluid must undergo some change in the economy, and this change itself be indissolubly connected with the essential actions of life. We know, in fact, that it undergoes a metamorphosis—that it is transformed into solids and thus becomes a part of the framework of the living being.

But if the solids of living beings be thus constantly appropriating to themselves substances from without, it is obvious, that, unless there be some means by which the solids themselves are consumed and removed from the body, there will exist no limit to growth from the commencement of life to its termination.

In animals, this consumption of the solids really occurs: in vegetables, with some few cases of exception,* it does not.

For the aliment of plants passes from the fluid state to the solid—from a state of motion, to that of repose, (which endures generally as long as the plant continues to be a living being, and in many cases, for a long time thereafter) without suffering further change than what occurs from a condensation of its substance, either by loss of water, or the appropriation of earthy bases.

In animals, on the other hand, there is a continual decomposition of the solids going on, at the same time that they are renewed from the aliment.

This consumption of the solids of animals is owing to the influence of oxygen, which they take into their systems by means of the respiratory apparatus. The carbon and hydrogen of the solids unite with the oxygen, forming carbonic acid and water; and at the same time, caloric, so necessary to the vital actions of animals, is generated and evolved as animal heat.

* These cases occur in the flowering of plants, maturation of the fruit, and germination of the seed, in all which, oxygen is absorbed and carbonic acid gas given off.

Herein animal and vegetable life totally differ; for the vegetable takes in carbonic acid gas, appropriates the carbon, and eliminates oxygen; animals, on the contrary, take in oxygen, and eliminate carbonic acid gas.

Assimilation, then, or the transformation of the fluid aliment into the solids, is a phenomenon common to all living beings. But when we come to compare one of these beings with others, we are struck with the facts, that they have not the same outward forms, that the aliment of one is not that of another; that the mode of appropriating to itself that aliment differs in each species; that their physical properties and chemical composition are diverse; in short, that in most of these particulars, one may differ from another as much as any two things in existence.

If we now enter the interior of these beings; if we examine with attention their structures and compare them with one another, the like facts are again brought before us;—namely, a striking dissimilitude of one to another. While we find some to possess a heart, stomach, lungs, liver, etc., we find others not possessed of even one of those organs.

In what then do beings so unlike as man and a vegetable agree? I have already said that a transformation of the fluid aliment into solids composing the frame-work of the system, was a phenomenon common to all living beings. This, then, is their *physiological* agreement. Examining their structure, we find them to coincide in two points, and two points only;—namely, the material of neither is homogeneous, but is composed of solids and fluids; and the solid portion of both is porous; that is, the fluids can penetrate intermolecularly the solids. Again, if we go back to their origin, we shall discover that they have not always existed as we find them. The specific form has been built up from other forms: man has become such from an embryo; the oak has grown up from an acorn. This, then, may be called their *historical* agreement. And these are the points in which not only man and a plant, but in which all living beings agree one with another. In any other

particular they may differ: here they are found to agree universally.*

The nature of life, then, it is obvious, must be sought for in those acts in which all living beings agree; which, as we have seen, are a transformation of the fluid aliment into the solids, and the formation of the adult structure.

From observation we learn that the aliment invariably enters the system in a liquid state, and is then termed the *nutritive fluid.* It afterwards may become solid, and in that state form an integrant part of the system. Now, it is amongst the molecules of the tissues that investigation has ascertained this change from the fluid to the solid state to occur; and of course, if the solid molecule again becomes fluid and is removed from the system, that change must also occur in the same spot.

Moreover, it is obvious, that there must exist a close chemical relationship between the nutritive fluid and the solids; since the latter have been formed from the former; and we know besides that most of the solids are easily converted into fluids. In fact, we find in the nutritive fluid all the chemical elements found in the different solids and secretions, which differ from each other merely in possessing a few elements more or less; or the same elements existing in different combinations.

* I am aware that physiologists mention other points of agreement, but it can be shown that they are all referable to the above. Thus Cuvier,—"absorption, assimilation, exhalation, development and generation are functions common to all living beings; birth and death the universal limits of their existence; an areolar, contractile tissue, containing within its laminæ fluids or gases in motion, the general essence of their structure; substances almost all susceptible of conversion into fluids or gases, and combinations capable of an easy and mutual transformation, the basis of their chemical composition."—*Règne Animal*, tom. i.

It is true that all living beings absorb, but absorption is not peculiar to living beings;—it occurs in dead substances, indeed in all porous bodies.

Assimilation, development, exhalation and secretion are consequences of nutritive action; whilst generation consists merely in placing a substance (the ovum) furnished by the parent under such conditions that it can absorb the nutritive fluid, and thus take on vital actions.

Again, birth is the mere separation of the offspring from the parent; and death, but the necessary cessation of one kind of action and the transition into that of another.

We have now all the points in which living beings agree, one with another. They agree *anatomically* in the *co-existence of solids and a nutritive fluid* of close chemical affinity, and capable of being resolved into each other; and secondly, in *porosity of texture*, so that the nutritive fluid may penetrate intermolecularly the solids.

They agree *physiologically* in the great phenomenon, *nutritive action*—to which absorption is antecedent, and of which, assimilation and secretion are consequences.

In nutritive action, therefore, we must seek the reason why living beings present phenomena so widely unlike those of brute matter.

I commence the inquiry with an extract from the celebrated chemist, Berzelius.

"A living being considered as an object of chemical research is a laboratory, within which a number of chemical operations are conducted; of these operations, one chief object is to produce all those phenomena, which taken collectively are denominated 'Life;' while another chief object is to develope gradually the corporeal machine or laboratory itself, from its existence in the condition of an atom, as it were, to its utmost state of perfection. From this point of utmost perfection, the whole begins to decline as gradually as it had been developed; the operations are performed in a manner less and less perfect, till at length the being ceases to live; and the elements of which it is composed, again set free, obey the general laws of inorganic nature."*

But although it is true that chemical compounds are formed in the living being; and that these compounds may be resolved into the elements which we find in brute matter, still by no means whatever can the chemist work backwards, and again form those organic compounds from the elements which he has set free. Elementary principles, such as carbon, oxygen, hydrogen and azote may be liberated from fibrine or soluble albumen, and, moreover, the exact proportion of each be ascer-

* Traité de Chimie, tom. v.

tained, and yet all the art of all the chemists has never yet been able to make them enter again into combination, so as to reproduce fibrine or albumen. How is this?

Without occupying our time with the "Moving Principle" of Aristotle, the "Amina of Stahl; the "Archæus" of Van Helmont; the "vis medicatrix naturæ" and a thousand other vagaries of the imagination; let us come at once to the state of physiological science at the present day.

On this subject, physiologists are divided into two sects.

The first of these maintain that the phenomena of life must be referred to the agency of a *force* or *power*, distinct from, and opposed to, the general affinities of brute matter.

The other sect maintain that the existence of any such force is a pure hypothesis; that there is no necessity or even good reason for its introduction; and that all vital phenomena, so far from being opposed to the general laws which regulate the operations of matter, are in reality but so many various manifestations of those laws.

The first support their tenets in this way:—

It is admitted that those compound substances which are formed in living bodies, cannot be imitated by the chemist. Let him bring carbon and oxygen and hydrogen together as he please, he cannot with his greatest skill and all his agents, produce one single compound such as is produced in living beings. He can neither form starch nor sugar, nor lignine, all of which are organic compounds formed of these elements in different proportions. Now, what is the art of the chemist? In forming compounds from elementary substances, what does he do, what can he do, but bring those substances in contact with each other. If they have affinities for each other, he can no longer control them;—they must of necessity obey those affinities;—he can neither limit, nor increase, nor diminish their play after it has once commenced.* These elements then (carbon, oxygen,

* Ad opera nil aliud polest homo, quam ut corpora naturalia admoveat et amoveat; reliqua natura intus transigit.—*Nov. Organum.*—Aph. iv.

and hydrogen,) will not combine of their own natural affinities, one to another, so as to produce an organic compound. We are, therefore, obliged to refer the formation of these compounds to another *force*, more powerful than the affinities of their elements, one to another. This force we term the "Vital Force;" and we use the phrase to designate some unknown power which we infer to be in operation, from the results we see. In truth, so far from framing an hypothesis, we are in reality only adhering more closely to phenomena. And the case is precisely the same with all other subjects of inquiry in physics. There are in every direction ultimate facts beyond which we cannot proceed. The word "attraction" is used to designate that tendency which one mass of matter has to approach another mass;—the word "affinity," to distinguish the approach of the particles of a substance to those of another. But in either of these instances is it possible to go beyond the visible phenomena? Has the unknown cause why bodies approach each other ever been revealed? Assuredly not. The words *attraction* and *affinity* are used merely to represent certain actions in matter, the efficient causes of which are unknown. In like manner we use the words "Vital Force." We employ the term to distinguish certain other actions in matter, which we see in their results to be different from those actions represented by the word *affinity*.

Concerning the intimate nature of this force or power, we feel it to be useless to speculate; just as it is useless in the case of attraction or affinity. Vital actions are ultimate facts, in the same way as chemical combinations, or the revolution of the planets, are ultimate and inexplicable.

Again, we see every day that organic compounds may or may not possess life. Sugar and starch are organic products and they may exist in the living vegetable or out of it; that is, they may be endowed with life or not. Fibrine or albumen may exist in the vital state or in that of brute matter. Therefore life must be a principle superadded to common matter; for if it were not, there would be no difference between fibrine and albumen in the living body and fibrine and albumen out of it.

Moreover it is idle to talk of Life as the result of organiza-

tion. Attentive observation of phenomena warrant no such conclusion, but indeed rather the reverse. It is true that life is never met with and cannot be conceived of apart from organization; but is organization ever met with, which at one time or other, has not been endowed with life? Is not in fact the organization built up by what we call the *vital force?* What two things on earth more dissimilar than the human being in the flush of manhood, and the embryo a week old? Where a greater difference than between the full grown oak and the acorn? And yet the embryo and the acorn were the primitive forms of these two beings, man and the oak. And what has thus built them up, but the vital force? Abstract this force, or principle, or whatever you choose to term it, from the acorn or the embryo, and what is the consequence? The acorn will never become an oak, nor the embryo a man. *Then* it is, that the usual, the ordinary affinities of matter come in play;—after the removal of this controlling power, the *vital force.* The chemical elements no longer subjected to a superior power, obey the general laws of brute matter: particle obeys the call of particle, and the organic fibrine is resolved into its elements, or moulded into new compounds.

Such are the arguments used by one class of physiologists. The reasons urged are unquestionably specious, nay, convincing to those who are not accustomed to close and abstract reasoning. But let us look a little more closely at the matter.

Life, in the other view of the case, is a general term employed to express a great variety of phenomena, which have agreement in certain points, but may be altogether different in others; just as the word "quadruped" is used to designate certain animals, which may resemble each other only so far as they all have four legs. For that this is really the case, one may satisfy himself by solving the question, what are those phenomena common to both a bird and a plant? It will be found that they agree only in possessing an areolar tissue in which certain actions are constantly going on. The results of these actions being different from what is observed to occur in brute matter, it has been thence inferred, that the chemical

elements which enter into organic compounds, are forced into combination by a distinct power superior to those general affinities, wherewith, observation informs us, all matter is endowed. The reasons advanced we think inconclusive and unsatisfactory.

Because (to commence this subject with a criticism) this thing which has been a *force*, a *principle*, an *agent*, etc., just as happened to suit the fancy of the employer, must necessarily be in one of three categories. It must be either a substance, the property of a substance or substances, or it must be merely expressive of a condition or state of things, which condition may be one either of action or repose—of rest or motion—static or dynamic.

Were life a *material* substance, it must of necessity possess the general properties of matter, and so be cognizable by the senses, and that such is not the case, it is scarcely necessary to mention. Nor can life, with logical strictness, be assimilated to the imponderables. Of the existence of light, heat, and electricity, we have the same evidence that we have for the existence of any thing external to us; viz., that of our senses. For the existence of life as an entity *per se*, we have no such evidence. Moreover, we are acquainted with many of the properties of these imponderables; they are the subjects of extensive sciences;—but what properties of life are we acquainted with? Those properties, termed *vital*, such as *sensibility* and *contractility*, are the properties of certain tissues and organs existing under certain circumstances, not of a particular substance called "life."*

* Bichat has no less than five of these *vital* properties. Later authors have reduced them to two, *contractility* and *sensibility*.

Now, what is contraction? It is but a closer approximation of particles, so that the columc of the whole mass is diminished. If cold be applied to the skin, it contracts;—if we prick or galvanize a muscle, or if we exert our will, it contracts. We know, in the last case, that if the nerve leading to the muscle be divided, no contraction will ensue. Hence, in all cases, there is some material cause (whether we have discovered it or not) producing the effect. Contractility is inseparably connected with the peculiar structure and chemical constitution

Those who would make life an *immaterial* principle, are surely guilty of framing a very vague hypothesis; which indeed may be very convenient, as it puts a stop to all further inquiry; and may be acceptable to those who suppose they learn any thing from admitting it; but which we have just as much reason to frame for the solution of any other phenomenon, and just as much reason to insist upon. But, in truth, this is one of those hypotheses which can neither be maintained nor refuted, since it is impossible for the human mind to frame any distinct notion of such a principle. It is a sound and nothing more.

Admitting, however, for the once, that it is possible to attain a clear conception of it, have we escaped our difficulties? Review the great variety of living beings; observe the innumerable diversities of form, and the multitude of organic productions. Has each species of living beings a *vital principle* peculiar to itself? If the answer be *yes*, the difficulty is by no means got over: the admission must extend far beyond this. A separate vital principle must be framed for every tissue and organ, the functions of which are different.* Now there is a time when the embryo exists without any of the organs being yet formed: where during this period are their peculiar vital principles?

of the tissue which contracts, and is, therefore, as much a *physical* property as any other.

Contraction, moreover, is not a phenomenon peculiar to living beings: it occurs also in dead substances. Metals expand by heat, and contract from cold; wood expands by absorbing moisture, and contracts when robbed of it (a)

Sensibility also can only be termed a *vital* property, in the sense that none but living beings manifest it. But neither do all living beings possess it; nor all parts of the living system of sentient animals. It is, therefore, not essential to life.

* "It is considered by many, and perhaps truly, that we are not yet prepared for a generalization of so high a kind, (that is, the hypothesis of life being a simple principle,) or, at least, that it would be more convenient for the analysis of vital phenomena to consider life as made up of several principles differing in their nature."—*Notes to John Hunter's Principles of Surgery*, by James F. Palmer.

(a) The difference between this species of contraction and that of the muscles, has been pointed out in another place.—See Chapter 10.

With regard to the different tissues and organs, and the functions they perform, it may be argued, that though the vital principle is identical in all, yet different effects are produced, because the materials on which it operates are different.* But this very argument carries with it the admission, that there are other causes besides the existence of a vital principle, why gastric juice is secreted from one organ, and urine from another; why muscular fibre is deposited in one place, and bone, etc., in another. After such an admission the *vital principle* may be rejected entirely;—it is no longer necessary to explain vital phenomena.

Again, plants and whole tribes of the inferior animals are capable of propagation by division. By cutting to pieces a single individual, we may make hundreds,—each of which will possess an independent life. Have we, in this case, divided the vital principle? How can we imagine the division of a thing which is not material?

If life be made a separate and distinct property of matter, the enormous difficulty presents itself, for us to conceive how matter can possess a property that is moveable; that may reside in a certain substance to-day, and, *without the occurrence of any change in its structure or chemical constitution*, be gone to-morrow; which must occur if death can take place without disorganization, as the vitalists contend.† That the properties

* Such was the opinion of John Hunter.

† "I have observed that animal matter may be in two states; in one it is endowed with the living principle, in the other it is deprived of it. From this it appears that the principle called life cannot arise from the peculiar modifications of matter, because the same modification exists when this principle is no more. The matter abstracted from life appears at all times to be the same, as far as our senses and experiments carry us."—John Hunter, *Principles of Surgery*, Chapter II.

"Our ideas of life have been so much connected with organic bodies, and principally those endowed with visible action, that it requires a new bent to the mind, to make it conceive that these circumstances are not inseparable. I shall endeavour to show, that organization and life do not depend in the least on each other; that organization may arise out of living parts, and produce action, but that life can never rise out of, or depend on, organization. An organ is a peculiar conformation of matter (let that matter be what it may) to answer some

of a substance may be dormant, it is easy to conceive; because it may have never been placed under those circumstances necessary for their revelation; but that matter, without a change of form, or of the disposition of its molecules can take on and put off again a property, is, we humbly think, an impossibility—a proposition irreconcileable with the notions of matter that our minds are constituted to entertain. For, (to come to the pith of the matter,) what is the real meaning of the words, *force, power, property,* etc.?

In strict philosophy, observation is the only admitted means we possess of obtaining knowledge. Observation and reflection upon what we observe, are the limits which bound in all human science. and beyond which the human mind cannot advance. "Homo, naturæ minister et interpres, tantum facit et intelligit, quantum de naturæ ordine, re vel mente observaverit; *nec amplius scit aut potest.*" To this aphorism of Bacon, our reason gives assent at once, for it requires no great expenditure of logic to prove that a dream is to be valued but as a dream; that an hypothesis until proved to be true, is but an assumption—in short, that in leaving the path pointed out, we turn aside from nature to pursue the meteors of the imagination.

Keeping then, our senses intent upon facts, what do they reveal to the mind? The existence of unremitting activity; of change—incessant change; of phenomena succeeding phenomena in endless rotation! But for any of these phenomena, where shall we find our ultimate reason? True: we may often take to pieces, as it were, some particular fact, and show that it is made up of a series of more general phenomena. But for any one of these general or *ultimate* facts, as they are called, who shall give a reason for its occurrence. Why may it not have happened otherwise; or exactly the reverse?

These questions none can reply to. But our minds are so constituted, that when we see an event occur, the belief imme-

purpose, the operation of which is mechanical: but mere organization can do nothing, even in mechanics, it must still have something corresponding to a living principle; namely, some power."—Hunter, *On the Blood*, etc., chap. i. sect. vi.

diately arises, and is irresistible, that the same event has ever occurred, and will again and forever occur, when the co-existing circumstances are the same. This belief is itself an *effect* as inexplicable as any other in the universe.

Therefore, beyond observation and our instinctive belief in the uniformity and invariableness of events when circumstances are the same, we know and can know nothing. What we term an explanation of a phenomenon, is a mere detail of other separate phenomena, which occurring in succession, have ended in the one to be explained, but all of which were previously the subjects of observation. When the chemist produces water by the mixture of oxygen and hydrogen gases, he presents us a simple fact;—ultimate and inexplicable. If he attempts to give a reason for it, and tells us the union is caused by the *reciprocal affinities* of the two substances, he but repeats the fact in another form; since *affinity* is but a word denoting that very tendency to union, which he attempts to explain by it. But when the natural philosopher explains why liquids rise in exhausted receivers, he seems to do something more; since he shows us how the result came to pass. Yet if we look more sharply into the subject, we shall find, that he has done nothing else than to repeat in a connected order, a series of minor phenomena, with most of which we were already acquainted. He shows us that the atmosphere, like all other terrestial bodies, tends to the centre of the earth, and therefore presses with a certain weight upon its surface; he then calls our attention to the constitution of fluids and the hydrostatic fact, that they press equally in all directions; finally, he proves to us that the pressure of the atmosphere has been removed on a portion of the liquid, whilst it is continued on the remaining portion; so that the rise of the fluid in the receiver is nothing new in itself, but is merely a new form in which old phenomena are evidenced.

Such then is really the philosophical statement of the subject. We can give no reason whatever for any simple phenomenon. Between two separate events which occur in immediate succession, we can observe no necessary connexion; so that no

person can predict any event which is single in itself, and has not heretofore been observed:—a fact of which the process of chemistry furnishes us abundantly with daily proofs. The rest of this subject is therefore, but a question concerning the use of language;—the application of certain words, as, *cause*, *effect*, *power*, *force*, *susceptibility*, *property*, *quality*, etc.

It must be kept in mind that in all the operations of matter, there is both action and reaction. In any change occurring between two bodies, one is not solely active and the other merely passive; but both are agents and both patients. When a child puts his finger into the flame of a candle, it is not the burning body only which is active, for although it has produced pain, it has also suffered—the finger having robbed it of a portion of its caloric. Or perhaps a better illustration may be drawn from the magnet which if it be fixed will draw a needle to itself; but if free to move and placed in the neighbourhood of a large mass of iron, will itself be drawn. So, also, when we place the opposite poles of two magnets together, we shall see them *both* moving and approaching each other. Now according as we intend our minds on any particular portion of the change, are we disposed to employ the words, *cause* and *effect*. If magnet A, be the object of our attention, we would say that magnet B is the cause of its motion. If we attend more particularly to B, we say its motion is caused by A. The *causes* of any change whatever, lie therefore, in all the bodies engaged in that change; as likewise the change itself (or effect) is never confined to but one substance.

But in a vast number of the events which occur on our planet, a portion only of the change produced, is perceptible;—the other portion not being discovered except after much investigation. For instance, in the example already given, every one experiences at once that a change is produced in the condition of his hand when it comes in contact with a burning body; but the change undergone by an incandescent substance is not so readily perceived. It is from this circumstance that the words *cause* and *effect* are employed as they usually are. The burning body is supposed to be the only substance which is active, because

we do not perceive the change it has undergone in itself, and we, therefore, say that it is the cause of the pain produced; or more loosely still, that the blaze has caused the pain. We also say "the fusion of metals is caused by the action of fire," because we attend to the change undergone in the metals, but not to that undergone by the burning body. But there are really causes on both sides, and effects on both sides. This truth is frequently only evident to attentive observers, particularly when the substances remain apart after the change has been undergone, yet when the bodies coalesce as in chemical unions, it may be made apparent to every one. Mix sulphuric acid and lime-water: a change will ensue, and we shall no longer recognise either earth or acid. If any one should now say, that the acid is the cause of the change in the lime, another with equal justice may say that the lime is the cause of the change in the acid; since the actions which result in the formation of the neutral salt, are reciprocal.

To the same circumstance, namely, that in many cases a portion of the change undergone is not perceived by us or unattended to, is owing to the employment of the words *power* and *susceptibility*. We use the word *power* more strictly in reference to the produce of the evident change; whilst the term *susceptibility* is employed in reference to the body that evinces the change. "Fire possesses the *power* of melting metals, and metals are *susceptible* of fusion by fire." The change undergone by the caloric escapes our observation, whilst that undergone by the metals is attended and referred to. But, as I have already said, *power* is exerted by both substances, and both manifest *susceptibility* of change.

The words *property* and *quality* mean the same thing, or differ only in their derivation. They are usually employed to denote what will happen conditionally. We say, "that water has the property of dissolving salt; or that it is a quality in water to melt salt;" and we mean merely, that if water be placed under certain conditions in contact with salt, dissolution will take place. By these words, therefore, we refer more particularly to the future, and express by them our belief that bodies, when placed in such or such circumstances, will develope

certain phenomena. When, therefore, we enumerate the properties by which any body is known, we speak of the coexistence of certain powers, or capabilities in that body to produce certain effects, and can mean nothing else; whether the existence of these powers is to be made apparent by immediate operation on our senses, or whether they shall affect us through the medium of other bodies.

Force is another abstract general term and is strictly synonymous with power; for the force of any body is that body considered as producing or as capable of producing some particular effect. "A cannon ball flies with immense *power*," or, "with immense *force*." In these phrases the words are convertible, and I know of no other in which they are not so.

As *force* then is nothing more than a word expressing the action of matter in producing change, and as the changes produced will of necessity vary according to the relations in which the bodies engaged, stand with regard to each other; it is obvious, that just as we change those relations we may multiply forces. Hence it is, that with regard to different species of effects, we have so many *forces* recorded as having produced them; such as the force of *attraction*, of *repulsion*, of *gravitation*, of *affinity*, of *cohesion*, of *elasticity*, of *inertia*, and hundreds of others. These general terms are of great use when they are taken for what they really are, merely short forms of expression; for without them, it would be necessary to go over in detail all the subjects of science, which, in these terms, are thus concisely referred to.

Matter and force, then, are not entities distinct and separate. Matter when closely scrutinized reveals itself to the inquirer as a principle of constant and unremitting activity; whilst force is the manifestation of this activity in the production of change. "Power," says Locke,* "makes a great part of our complex idea of substances,"—but the truth is, there is not a notion we can frame of matter in which power is not essentially a component. For there can be no bodies without qualities of some kind; nor indeed do we, nor can we know any thing of bodies

* Essay on the Human Understanding, B. 2. chap. II. §. 7.

except their qualities; and those qualities are but the expressions of so many powers in bodies capable of producing so many various effects.

The *Inertia* of matter is a thing inconceivable, if the term be used to signify that matter is *powerless*. The true meaning of the phrase is simply this: "no body can change its condition without the intervention of some other power."* But can we conceive a body either in motion or at rest to be absolutely *inert*—void of power? Surely not; since in either state it is capable of acting on us and upon other bodies. Nay, in either condition it is *continually* exerting its activity; for if it be a motion, its activity is manifested by the motion itself; and if at rest, its particles are bound down, each to each, by the *force* of attraction.

We are acquainted with matter through the medium of our senses. It is, therefore, relative to us; for were our nervous substance altered, our sensations would be different. In these sensations we experience the effects of something, which from a fundamental belief,—(an inexplicable and ultimate fact in itself,) we imagine to exist without us, and to produce them. What that something is, apart from its powers of causing those feelings, it is impossible for us ever to know. But it is evident from this statement itself, that matter is a principle of activity. For to produce sensation within us, it must have the *power* of doing so;—in other words, it must *act* upon us. And again, when we turn our attention, not to the immediate action of matter upon ourselves, but upon itself, what can be more wonderful and incomprehensible. We see the same occult, mysterious activity exerted when two globules of mercury approach each other and coalesce, as well as in the earth whirling round the sun, or the sun retaining the earth in its orbit. Nay, if we regard closely, we shall find that this activity is exerted unremittingly, unceasingly, at all times, and in all places; as well at rest, as in motion.

* "To say that matter is inert, or has *inertia*, as it is termed, is only to say that the cause has been expended in producing its effect, and that the same cause cannot (without renewal) produce double or triple its own proper effect."—*Discourse on the study of Nat. Philosophy, by Sir John Herschell.*

Therefore, as force in its most general sense, expresses *action;* and in a limited sense, a certain *mode* of action; the vital force, in the production of vital phenomena, must be regarded, not as a thing apart from the substances engaged in these phenomena, but as a convenient term used to express a particular sort of action, attended with certain results.*

Without urging other objections which might easily be found against the hypothesis of a *vital force,* let us now advance the arguments of the other side. It has already been said that *life* must be one of three things: it must be a substance, the property of a substance or substances, or it must merely express a condition or state of things. It has been shown that it can be neither of the two former, it must therefore come within the third category.

This condition may be one of action or repose: *vitality* may express the latter; *life* the former.

All living beings, as we have observed, agree in two points; namely in the formation of certain compounds from their ali-

* Inesse corporibus organicis vivis ad unum omnibus peculiarem vim, ipsis connatam, et quamdiu vivunt, perpetuo activam et efficacem, statutam ipsis et destinatam formam generationis negotio primo inducendi, nutritionis posthac functione perpetuo conservandi, et si forte nutriate fuerit, quantum fieri potest, iterum restituendi.—*Blumenbach, Inst. Phys.* § 591.

This *nisus formativus* of Blumenbach, (the *vis essentialis* of Wolfe—the *nutritive force—vital force,* etc., of later writers) represents to us merely unknown circumstances. Like the x of the algebraists, we should employ it to represent not some being existing *per se,* but merely those circumstances in which living matter exists; which are essential to the phenomena of life, and therefore, the causes of them. These circumstances are, 1st., matter of a certain chemical constitution; 2ndly., a peculiar structure in this matter, so that it is rendered permeable to fluids; 3rdly., a nutritive fluid, which is to permeate intermolecularly the solid or semi-solid matter, to which it must also bear a close relation in chemical constitution. These postulates being fulfilled, the phenomena of life must necessarily arise out of them. The inherent forces of matter set all in motion, and maintain a particular sort of action as long as circumstances remain the same. The nutritive fluid is absorbed; chemical changes occur between it and the molecules of the solid; and as a consequence, some portions of it are retained in a fixed state, whilst other portions are rejected. In animals a portion of the solid is also resolved at the same time into the fluid state and thrown off. In these phenomena we have all the essential operations of life:—absorption, assimilation, and secretion.

ment; and in the building up, as it were from the embryo state, a machine, complicated in many instances, made of tissues and organs, and possessing a certain form peculiar to the species.

It is contended that the inherent forces of brute matter are by no means capable of producing either of these phenomena. Let us, however, examine this subject more closely and first, in the formation of organic compounds.

All bodies possess certain properties which are common. Thus we speak of gravity, extension, and resistance as general properties; because wherever we find matter, we find it possessed of these properties. But besides these common properties, there are others which are peculiar, and it is by these peculiar properties that we distinguish one kind of matter from another kind. Thus, gold and silver have common properties, but each of them has also properties peculiar to itself, by which it is distinguished from the other, and indeed from all other substances.

But the properties of a substance can be known to us only so far as they have been the subjects of observation. Thus, chlorine was known to possess certain properties; but it certainly could never have been known until the test of experiment, that it possessed that of dissolving gold. In truth, this is a necessary corollary from the fact, that the properties of bodies are nothing apart from the bodies themselves, but mere words, employed to designate certain phenomena, which will appear, if certain circumstances co-exist. Now, we cannot see any one substance in every possible relation with all other substances, and therefore, it is plain, that *all* the properties possessed by a substance can never be known to us. In truth, the properties of chemical elements, as set down by the chemists, are only a few of the most obvious; and chemistry is from day to day, developing the existence of properties, before unknown and unsuspected.

If we examine phenomena with attention, we shall find, that in every change in nature there are opposing forces overcome. Such a thing as matter undergoing *spontaneous* changes is inconceivable and absurd. No body will ever undergo change

as long as the circumstances under which it was formed remain the same; for in whatever state we find a body, it is exerting constant, unremitting activity, and to change that mode of action for another, some other power must be introduced. But these opposing forces may be stronger than those tending to produce a change; and hence, it follows that a body may possess many affinities which, on account of these opposing forces, remain quiescent and unobserved. Thus gold, it is possible, may have a tendency to dissolve in water, but from the paramount influence of cohesion exerted among the molecules of the metal, the tendency can never be made apparent. For the same reason, "one salt may have a greater affinity for water than another, and yet be less soluble."*

Again, the properties of a substance being merely the manner in which that substance will act under particular circumstances, it is obvious, that an elementary substance cannot assume or lose a property; its actions being the result of inevitable necessity. Therefore when two or more elements combine, the properties of the compound can be nothing but the development of the original tendencies of the elements; for a compound can be nothing more than the co-existence of the different elementary molecules in juxta-position; and such being the case, it is evident, that there must occur a composition of properties;—in other words, that the elementary molecules must act with a joint influence on those of other substances with which they come in contact. Hence, the great difference between the properties of a compound and of its elements when separate. To give an illustration: an alloy of silver and platinum is dissolved when immersed in nitric acid, whilst platinum, when presented alone, resists the action of the solvent. The reason of this is, that though the last-named metal has some affinity for the acid, the paramount force of cohesion presents a union. The presence of the silver undergoing oxidation, exerts its power over the platinum, breaks up the cohesion and effects the combination.

* Traver's Chemistry—General Remarks on Salts.

Therefore, as we have never observed any one substance in every possible relation with all other substances, by which means only we could obtain a knowledge of all its properties, it follows, that after two substances have entered into combination with each other, the phenomena that will ensue, when a third substance is presented, are altogether beyond prophecy. The chemist himself would think it the most idle and ridiculous thing in the world, for any one to make such predictions. He knows too well that the properties of all bodies must be learned by experiment.

Again, as the number of elements in a compound are greater, it is obvious, that the properties of the compound will be more striking and unexpected.

Now, it is in living beings that these elementary principles are known to be most numerous. The compounds of inorganic matter consist, generally, of two elements; rarely of three; and scarcely ever of more. But the simplest organic compound contains three at least, whilst higher in the scale of life, their number is greatly augmented. In man, fourteen or fifteen have been discovered. But if the difficulty of foretelling the properties of a compound, from a consideration of its elements, be insuperable and the attempt idle, what shall we say, when we remember the effects produced by mere difference of proportion? When we remember that by a mere transformation or transposition of elements or proximate compounds, we may produce two or more substances of entirely different properties, yet possessing ultimately the same elements in the same exact proportions? When we know that the mere *presence* of another substance may produce decomposition, or cause the formation of other compounds? When we recur to the fact, that a body already undergoing chemical change may exercise a power upon other compound substances, and cause new combinations of their elements, without itself participating in that change;—as in the case of sugar, converted into alcohol and carbonic acid by the mere presence of yeast?

We insist, therefore, that it is altogether from misconception

of the nature of chemical combinations, that it is so roundly asserted that matter operating by means of its own forces, cannot produce an organic compound. But why is it, then, that the chemist cannot in his laboratory produce an organic compound? Simply because he cannot place his materials under those circumstances *essential* to their production. Sugar and gum are composed of carbon and water; but regard, for an instance, the multiplicity of forces, conjoined and operating at the same moment, required to make water and carbon unite. In the first place the leaf must be of a certain chemical constitution, be possessed of a certain structure, and be well supplied with water. There must also exist a certain temperature; light must be present; and the leaf must be of a green colour. If any one of these conditions be withdrawn, the union of the two substances will not take place. Now, will it be contended, that the chemical elements of the leaf being given, with the whole structure of the living plant, together with every other circumstance the same; the carbonic acid of the atmosphere would not be decomposed, and that the carbon would not unite with the water? That, in short, there must be introduced into the case the agency of an occult, mysterious principle, before the union could be effected? Assuredly those who thus argue, are under the *onus probandi;*—they must prove their assertion or their *vital principle* must remain a most vague and gratuitous hypothesis.

Is it fair to argue from our ignorance? Because we do not know the precise manner in which a phenomenon occurs, shall we boldly assert the existence of new agencies in nature? Why, by such logic we may multiply new principles almost *ad infinitum.* For instance, the nature of the diamond is perfectly well known; but can the chemist work backwards and form diamond from carbonic acid gas? Can he, in short, form any of those beautiful gems found in the mineral kingdom; such as topaz, ruby, etc.? He cannot. Then will it be urged that these inimitable productions of nature were formed by some force superadded to matter? Will some peculiar principle analogous to

that termed *vital* be introduced to account for their formation ?* If so, let us at once go back to our exploded philosophy. Let us believe again that nature abhors a vacuum; and that this is a very satisfactory reason for the rise of liquid in exhausted receivers. Let us believe that the splendid researches of modern geologists amount to nothing; and that the impressions of organized beings, found in rocks, are in truth not those of beings once alive, but the productions of the *Vis Plastica* vainly labouring in the bowels of the earth, to evolve the forms of life. In short, let us shut at once the book of Induction, and open that of Hypothesis; which, though it really teaches us nothing, yet gives a pleasing play to the imagination, and gratifies our indolence by relieving us of all farther trouble.†

But it is asked, how comes it that tissues so various in struc-

* "Cudworth's hypothesis of a plastic nature has had, however, some partisans, though rather among physiologists than metaphysicians. Grew adopted it to explain vegetation; and the plastic nature differs only, as I conceive, from what Hunter and Abernethy have called life in organized bodies by its more extensive agency; for if we are to believe that there is a vital power, not a mere name for the sequence of phenomena, which marshals the molecules of animal and vegetable substance, we can see no reason why a similar energy should not determine other molecules to assume geometrical figures in crystallization. The error or paradox consists in assigning a real unity of existence, and a real power of causation, to that which is unintelligent."—*Hallam*, *Literature of Europe*, vol. iv. p. 109.

† Gestit mens exilire ad magis generalia, ut acquiescat: et post parvam moram fastidit experientiam: sed hæc mala demum aucta sunt à dialectica ob pompas disputationum.—*Nov. Organum*, Lib. i. aph. xx.

Partez d'un principe vague, indéterminé; prenez pour base de votre étude une cause de la vie, un principe vital dont la nature, et partout les attributions, sout inconnues, que rien ne restreint, et par conséquent ne précise, qui se prête à tout, parce que n'ayant rien de connu ou peut arbitrairement le douer de toutes les facultés imaginables; alos ce principe, qui vous expliquera tout en paroles sans vous expliquer rien en réalité, qui vous expliquera ainsi les faits les plus extraordinaires, certaines ou douteux, vrais ou controuvés, vous y tiendrez avec d'autant plus d' opiniâtreté qu'il favorisera d'avantage votre paresse et votre amour-propre c'est ainsi qu'on apprend à mépriser l'anatomie, la physiologie positive et toutes les lumières que peuvent nous fournir les autres sciences naturelles; c'est ainsi qu'on entrave les progrès de la véritable science de l'homme, et qu'on l'empêche de marcher vers la certitude dont elle est susceptible.—*Dugès*, *Journal de Médecine*, tom. ii. p. 347.

ture, and of such diverse chemical constitution,—how comes it, such various secretions are formed in different localities, and all from one common substance, the arterial blood? It is answered, that these different formations are owing to the different circumstances under which the blood reacts with the solid molecules.

All the organs and tissues of living beings, if they differ in function are endowed with characteristic marks, which distinguish them from each other. The leaves differ from the petals of the flower, the muscular fibre, from the nervous substance, and so on. We must therefore believe the interior structure or chemical composition of these organs to be different, each from each. Again, into all the organs of a living being the same pabulum enters: a homogeneous fluid, formed from the aliment, is distributed to every tissue. The same common sap may nourish very different organs and tissues, and produce very different fruit, as we see in grafted trees. The same homogeneous blood is distributed to every tissue in the human body, from which muscular fibre is formed in one part, bone in another, nervous matter in a third, gastric juice in a fourth, and so on. Now observation tells us that it is in the ultimate structure, that the nutritive fluid comes in contact with the solid molecules, and that there occur those phenomena which are the essence of life. It is, therefore, maintained that these different depositions in different organs are to be accounted for, either by diversity with regard to their chemical elements, or their chemical elements being the same, by a difference in their secondary and tertiary compounds, and the manner in which they are united to each other. Hence will arise diversity of structure; for structure itself is but a *consequence*. In fact, can we do otherwise than infer that under such circumstances there must of necessity be a difference manifested in the results? Can any one believe, that if the kidney and parotid gland were of the same exact chemical composition and possessed of the same ultimate disposition of molecules, one of these would secrete saliva, and the other, urine; being nourished as they are by the same homogeneous fluid? If any one can believe this, I ask him, why it

is that when any foreign cause intervenes we have very different results? Why it is, that when the nutritive fluid or the solids are altered in chemical constitution or in the mere arrangement of their particles we have lesions of nutrition and secretion—a production of substances not found in health? Is the *vis medicatrix* altogether powerless?

From what has been said, it is plain, that to account for the formation of organic compounds, we have no good reason for saying that they are not solely produced by the operations of matter upon itself. The chemist it is true, cannot form albumen or fibrine from the elements of those substances, and for a very plain reason,—he cannot command the circumstances under which they were originally formed, and which were absolutely necessary to their formation.

In reply to all this, we are called upon to observe and explain the very different phenomena which ensue when life ceases. Now we consider that the changes which ensue after death, so far from disproving what has been said, give us, in fact, a strong support. Death, we contend, can never take place without disorganization; for as life is essentially a chemical action of a particular kind going on between certain substances, it is plain, that the phenomena attending on, and characterizing that action, will go on until the relations between the solids and fluids, necessary for their subsistence, cease to exist. In order, therefore, to put an end to life, it is but necessary to change the existing relations of the solids and the nutritive fluid. And this may be done in three different ways:—by mechanical violence; by chemical agents, or by the abstraction of aliment. In vain are offered in reply, the instances of sudden death from poisons. These agents *do* produce disorganization; that is, destroy those relations between the solids and nutritive fluid necessary to life, and just as effectually as the mill-stone destroys the organization of a grain of corn. A drop of prussic acid is placed on the tongue of an animal, it is absorbed, and a sudden change is produced in the condition of the whole nervous substance. This is amalgamated, as it were, with the other solids, and no change can affect it which does not affect them.

It is not strange, therefore, that the compounds of an organized being, take on other actions when the circumstances, productive of them, no longer exist. In truth, changes somewhat similar are occurring in animals during the whole course of their living existence; as must be obvious when we recall the fact, that their particles are in a state of constant renovation. And is not this a better and more rational explanation than to say vaguely, that the *Vital Force* has been removed. For, (unless we take it metaphorically) if it be removed, whither has it been removed? If it be flown, whither gone? Or indeed, what is it, or what can it be?

Thus much for the formation of organic compounds. But living things pass through a series of forms until they reach what may be called the adult structure, characteristic of a species. The oak takes its origin from an acorn; man, takes his from the condition of an embryo. We must, therefore, explain the general causes of the formation of the different tissues and organs; in short, the building up of the adult organization.

"It is a rule" says Cuvier, "without an exception, that all living beings have adhered, each to a similar being, which is its parent." This proposition though so positively expressed by Cuvier is by no means admitted by all physiologists: there are many who believe in what is termed "equivocal generation;" but for the present let us assume Cuvier's law as true.*

Let us begin our inquiry with life in its humblest revelations, as in the vegetable. The seed is a product of the organic actions: it has been formed from the parent vegetable. From this parent it is separated in the course of things, and becomes an individual being existing by itself. But we have found that *life* is a word expressing certain actions attended with certain results. Therefore when we present a bean or a grain of corn to a person and ask him if it be alive, what does he mean by saying it is? There are no changes going on in the bean;—there is no motion of which we are cognizant;—there is no nutritive action—no absorption, assimilation nor secretion. What then is

* On the subject of equivocal generation consult Burdach, tom. i.

meant when it is affirmed that it is living? Surely merely this; that from certain appearances we judge that if the bean be planted in the earth at the proper season, certain changes will take place, the result of which will be the formation of the perfect plant. In short, the bean possesses *vitality,* but as yet, no *life.*

To place the subject in another point of view, let us suppose two beans gathered at the same time from the same plant. Let one of them be planted immediately, or in the next season: a certain series of phenomena will ensue, the result of which will be the production of a vegetable bearing leaves, flowers, and finally seeds, precisely as in the case of its parent. This series will come to a termination in a month or two;—the plant dies and is resolved into brute matter. But if we take the other bean and place it in a drawer, and keep it secure from moisture and insects, what will be the result. Why, that the bean will exist unchanged for any number of years, ten, a hundred, or a thousand, at the end of which, if it be placed in the earth, there will occur the very same train of phenomena that took place in the other a thousand years before.* Here, then, has been a duration of life far beyond that allotted to the growing vegetable. How is this to be accounted for?

It is answered, that in the never-ceasing course of change, the seed has been formed, and so formed or organized, as to fit it under certain circumstances to become a vegetable. But for the *primum mobile* of the necessary changes, it is dependent on two things;—heat and moisture. When placed in the earth it meets with these. It is now merely matter in contact with other matter fitted to act upon it; and a change is produced in its condition. And this change is produced, not by any force

* On dit avoir fait germer des haricots conservés depuis soixante ans, et des graines de sensitive, après cent ans d'existence.—*Dict. des Sciences Nat. Art. Vie.*

Some seeds retain the power of germinating for an indefinite length of time; since the wheat usually wrapt up with Egyptian mummies will often grow and germinate, as well as if it had been gathered the preceding harvest.—*Library of Entertaining Knowledge, Insect Transformations*, vol. i. p. 29.

See also, De Candolle, Physiol. Veg., tom. ii. p. 618.

or principle which is superadded to the material of the seed, and which, therefore, can be supposed to exist independently of the seed; but by the inherent activity of the substances composing it, set in motion by heat and moisture. The result which we see,—the change that has taken place, is the manifestation of this activity;—the effect entirely of the nature and arrangement of the different substances composing the seed, together with the peculiar circumstances in which it has been placed and acted upon.

It is evident, that after the first change in the condition of the seed, it cannot be the same thing it was before that change. It is another thing. Now, besides heat and moisture, it is in the presence of other matter; of the solid materials of the soil; of salts held in solution by water, by all of which it is more or less affected. Therefore the seed is undergoing in the earth a constant, a perpetual change. Perhaps at no two seconds of time is it the same identical thing. The result of all this is the growth of the seed. It springs in consequence above the earth, and is then placed in close relations with other bodies. It meets with light, with the oxygen and carbonic acid of the atmosphere, with a larger quantity of heat, and with electrical currents. It is subjected to impulses on its frame from winds, rains, and so on. From these causes, other changes take place,—developed in leaves, bark, buds, flowers, and finally, (to come back to the point of the circle from which we set out,) seeds, fitted in their turn, to produce the like phenomena under the like circumstances.*

This series of cause and effect may be broken upon, and then we have other phenomena. If the seed in the drawer should there meet with moisture and heat, it would put on the very same changes that first occur when it is planted in the earth; but having gone through these, and not meeting with a constant supply of moisture and those other substances necessary for its evolution, it passes of necessity into other changes

* A bien considérer les choses, la nutrition et la génération sont deux modes du même phénomène.—*Massey.*

and is decomposed. It is thus by some eruption of the order of nature that all her monstrosities are produced. In her established order she is always regular, beautiful and harmonious.

In most vegetables and in some animals, the process of generation is confined to one individual. The male organs supply to the female a certain substance which seems to be essential, and without which, the ovum or seed is not fitted for further development. The same thing holds where the sexes are in different individuals. The semen of male animals answers precisely to the pollen of plants; as does the uterus of the female to the earth, which is the matrix of the seed. Therefore it is plain, that the same reasoning will apply to the formation of the animal organization, that are applied above to the vegetable.

But "life cannot be the result of organization because the organization itself is the effect of life." This is but a poor piece of sophistry. It is as if one should say, "combustion cannot be the cause of the union of oxygen and carbon, for their union is the cause of the combustion." The actions of life result from the inter-penetration of the solids by the nutritive fluid. Certain relations exist between the two, essential to those results which characterize life as differing from other chemical actions. If these relations are destroyed, chemical actions still go on, but they differ from those of life, and they end in different results. For life is not combustion, nor fermentation, nor putrefaction, nor eremacausis, (to borrow a word from Liebig,) nor any other sort of chemical action but its own. It is a chemical action *sui generis*, ending in certain specific results, and differs from all other sorts of chemical actions, as all of the above mentioned differ from one another. The results which characterize vital actions; the formation of an ovum in the parent; evolution, or the formation of the different tissues and organs; birth, or the separation of the embryo from the parent; growth until maturity; gradual decay; and necessary death, or the passage from one species of chemical action into another. As long as certain relations between the nutritive fluid and the solids are maintained, life is a neces-

sary act. As long as the organization of the acorn is perfect, it is fitted, if placed in the earth, to become an oak. The embryo is in a condition analogous to the acorn in the earth; and as long as its organization is unimpaired; as long as it receives its supply of nutritive fluid; it will not only grow and live, but growth and life are the inevitable and necessary effects;—just as much so, as an explosion is a necessary result on the contact of gun-powder and fire.

There was unquestionably a time when no living being existed on the earth. From some unknown combination of circumstances that occurred in lost geological eras, carbon united with water, organic matter was formed from inorganic, and life commenced. As these circumstances were general, doubtless many myriads of living beings were at the same time produced. But accordingly as the circumstances varied in some particulars in different cases,—according to the action of external forces upon them,—would there necessarily be some modification of existence, and of the directions, which, the vital actions once set in motion, would assume. These primary organic beings may be compared to the ova of plants and animals, all of which, to whatever class they may belong, are closely allied in external form and chemical constitution.* But these ova are situated differently;—they are evolved under very different circumstances; hence, the immense variety of forms produced. From these general causes, and from the progression of change in the constitution of the earth, those modifications have arisen, which we have generalized into varieties, species, genera, orders, classes, divisions, and kingdoms.

This question is not one, the solution of which may be a matter of indifference. Why not, (we have heard it said,) study the science of life as we study other sciences;—collect

* The nearest approach which the vegetable and animal kingdoms make to each other, is not in the most perfect vegetable and the lowest or simplest organized animal, but in the lowest and rudest forms of *both* kingdoms, and likewise in their ova. To use a metaphor of Coleridge, they (the two kingdoms) are "two streams from the same fountain indeed, but flowing the one due west, and the other direct east."

the phenomena and arrange them in the order of cause and effect, but leave the question of the essence of life as one we cannot fathom? We answer, because that by so doing we make a wrong start;—we commence with an hypothesis which is false. Because, the very main fact,—the key-fact to the right understanding of all the rest, is not comprehended in the scheme. The hypothesis of a "vital force," as a thing independent of the substances manifesting vital phenomena, is an error, and the parent of innumerable others;—*chimæra chimæram parit.* Well and consistently may physiologists reject the splendid discoveries of modern chemistry, if, *à priori,* be assumed the existence of a force, which can and does resist, pervert and control the chemical forces of matter.* All our inferences concerning the processes of digestion, respiration, secretion, nutrition, etc., must be surrendered, for they are literally worthless:—we have laboured in a barren field. But, in truth, in thus referring vital phenomena to a mysterious principle of which we can form no idea, do we act more philosophically than the Indian who refers all natural operations to the Great Spirit; or than the old woman, who refers every thing to the Will of Providence?

Error, when it has once sprung up in the human mind, is not easily eradicated; especially, if sown in early life; nourished during our education; and strengthened by the influence of great names. The history of philosophy is a record of this truth. Phenomena were once explained by a *horror vacui* or *quinta essentia.* Astrology survived many years the birth of astronomy

* Il s'en faut beaucoup, à notre avis, que la question que nous venons d'examiner soit une chose oiseuse. Si nous avous cru devoir la prendre au sérieux, c'est que le système que nous combattons, savoir que presque toutes les fonctions dont il à été fait mention dans les précédentes considérations, ne constituent ni des phénomènes physiques, ni des phénomènes mécaniques, ni des phénomènes chimiques; c'est que ce système, repétons-nous, ne tend à rièn moins qu'à frapper d'une nullité anticipée toutes les recherches, toutes les expériences physiques, mécaniques ou chimiques que les physiologistes pourront entreprendre pour expliquer ces fonctions. Or, nous le demandons, quel serait le sort de la physiologie, sur quel progrès pourrait-elle compter si l'on interdisait à ceux qui la cultivent le champ des expériences de ce genre.—*Bouillard, Journal de Med. et Chirurgie,* tom. iii. p. 464.—Note.

as likewise, did alchemy that of chemistry. From this last science, also, may we draw an illustration apposite to the matter in hand. All acquainted with the science, must remember the doctrine of Phlogiston—the *principle* of levity and inflammability. When a metal, after being burned, weighed more than before, and was no longer inflammable, it had lost its phlogiston;—when the calx, after being mixed with charcoal, was reduced to the metallic state, the metal had regained its phlogiston from the charcoal. Lavoisier overthrew this doctrine by demonstrating the true causes of the phenomena; yet many, who receive without hesitation the doctrine of a vital principle; can look back with wonder upon the obstinacy of Priestley, who maintained the exploded theory to his dying day.

Of a "vital principle," however, we can frame no more distinct notions than we can of phlogiston. As soon as we separate these principles from the substances which manifest the phenomena, they are words and nothing more.

A metal, after being burned loses its "phlogiston;"—organic matter, after undergoing certain changes, loses its "vital principle;"—the calx, burned with charcoal, is reduced to the metallic state, having regained its phlogiston;—organic matter, being digested, becomes a part of the living being, having regained its "vital principle." The parallel is perfect.

Another obstacle to the overthrow of long received opinions is our fondness for whatever is mysterious. To some minds, the nakedness of truth is appalling;—the roseate twilight of poetry being far more charming and attractive. It gladdens the imagination to occupy itself with what we deem the judgment cannot reach, and we shall scarcely take the trouble to fathom a subject which is particularly pleasing to the imagination. Superstition, soon, usurps the throne of reason; and questions, in themselves, perfectly innocent,—questions, that it is the duty of philosophy to propound, and, if it can, to answer,—become thus to be regarded with a holy horror. But this factious mystery, with which we enshroud natural objects, is the bane of science; whose object it is to lay bare the train of phenomena in their natural order of sequence. It, besides, diverts the mind

from the perception of that great, that eternal mystery, which lies at the bottom of all things. "All is wonderful, or nothing is." The existence of a grain of sand with its powers and capabilities, is as incomprehensible and as wonderful as the existence of a star. He, who recognises this great truth, will smile at all human efforts to aggrandize what is already infinite, or to render more sacred the awful mystery of the universe. If we must have mystery, let us seek it there—in "that which lies at the bottom of appearance," and remember always, that, *boni viri nullam oportet causam esse, præter veritatem.*

ADDITIONAL NOTES.

VITALITY OF THE BLOOD.

The substitution of a "vital principle" in place of the inherent properties of matter, has entangled the supporters of the hypothesis in inextricable difficulties. On this subject—the "vitality of the blood," let us hear John Hunter, the author of the doctrine.

Hunter infers that the blood possesses life—

1. From the effects of heat in incubation;—a living egg is hatched; a dead one putrefies.

2. From the effects of cold on the living and on the dead egg. Take one of his experiments in his own words. "A new-laid egg was put into a cold atmosphere, fluctuating between 17° and 15°, it took above half an hour to freeze; but when thawed, and put into an atmosphere at 25°, viz., nine degrees warmer, it froze in half the time; this experiment was repeated several times with nearly the same result."*

Here is another. "A fresh egg, and one which had been frozen and thawed, were put into the cold mixture at 15°; the thawed one soon came down to 32°, and began to swell and congeal; the fresh one sunk first to 29° and a half, and in twenty-

* A Treatise on the Blood, etc., by J. Hunter, chap. I. sect. vi.

five after the dead one, it rose to 32°, and began to swell and freeze."*

"Similar experiments were made on the blood: after a portion of blood had been frozen, and then thawed, it has again been frozen with a similar quantity of fresh blood, drawn from the same person, and that which had undergone this process froze again much faster than the fresh blood."†

3. From the resemblance of the coagulation of the blood to the stiffening of the muscles after death.

4. From the resemblance of coagulation and the solidification of blood in the tissues.‡

The reader must bear in mind that John Hunter considers *life* as a principle which may exist apart from the organization, and therefore that he uses the terms "living" and "dead" in a peculiar sense.

It will be observed, then, that the first and second reasons assigned, are founded on the different effects of heat and cold upon two eggs, one of which possesses *vitality*, and the other does not. Now, as vitality in the sense I use it, signifies nothing more than a mere condition—a fitness in organic matter to take on when peculiar circumstances exist, certain specific changes and to develope, thereby, certain phenomena (the sum of which we term *life*) we admit, at once, that one egg possesses vitality and that the other does not. But why, or how does one possess vitality? And how is vitality lost in the other?

In order that any substance may take on vital phenomena, it is necessary, as already shown, that it possess a peculiar chemical constitution, and that at the same time, its molecules be arranged in a peculiar manner. These requisitions being fulfilled, it will go through a series of continuous changes when the necessary circumstances are present. Among these circumstances a certain temperature is one. If the temperature be too high, coagulation of the albumen occurs; if too low, congelation; by both of which we not only destroy the molecular arrangement of the body (egg) but in fact, we alter its chemi-

* Loc. cit. † Ibid. ‡ Op. cit.

cal constitution. Hence when an egg has been once frozen and caloric is again applied to it, though it be of the precise degree that would produce the vital phenomena in other circumstances, putrefaction, or some other change ensues;—the pristine arrangement of its particles having been destroyed by the congelation and its chemical constitution altered.

As for the fact that an egg takes a longer time to freeze at the first, than it does in subsequent attempts, it proves nothing more than this,—that the affinities which held the molecules in their pristine arrangement, were sufficiently powerful to resist the influence of cold to a certain degree. Water, under certain circumstances may be cooled almost to zero without becoming solid. The same principles—the like affinities that prevent congelation in the one case, prevent it in the other. Similar reasoning will apply to the blood.

As to the third reason, it is obviously illogical to infer from one obscure phenomenon, the cause of another equally obscure.

But the chief argument is derived from the coagulation of the blood and the resemblance between that phenomenon and the transformation of the blood into the solid tissues. "Coagulation I conceive," says Mr. Hunter, "to be an operation of life; and I imagine it to proceed exactly upon the same principle as the union by the first intention; it is particle uniting with particle, by the attraction of cohesion, which in the blood forms a solid."* If then coagulation be an operation of life, what keeps the blood fluid? We are told that "it (the blood) has the power of preserving its fluidity; or, in other words, the *living principle* in the body has the power of preserving it in this state."†

It must not be supposed by the reader that the living principle here referred to, is that supposed to exist in the solids; Mr. Hunter contends that the blood is itself alive. "For," says he, "if the blood had not the living principle, it would be, in respect of the body as an extraneous substance."‡

So then, the living principle is the cause of the fluidity of the blood, and also the cause of a directly opposite condition, coag-

* Op. cit. chap. I. sect. ii. † Op. cit. chap. I. sect. vi.

‡ Ibid.

ulation. All this confusion and contradiction has evidently arisen from giving an independent existence to that (life) which is a mere action, a mode of existence.*

The nutritive fluid coming in contact with the molecules of the tissues, gives rise to certain actions which we term vital actions or life.—The blood, therefore, is as necessary to vital phenomena as the solids, and of course is just as much alive. Life cannot exist in animals without blood, any more than it can exist without solid parts; it is the *result* of both blood and the solids, and therefore it cannot be logically said, to reside in either of the agents producing it.

The fibrine of the blood, however, though not organized is organizable, and capable under the necessary circumstances of taking on vital actions, and therefore we may correctly say that it possesses vitality—understanding thereby that vitality expresses a mere condition.

Liebig's Opinions of the Vis Vitæ.

I have shown in the foregoing essay that the nature of life, that is to say, the nature of these actions which distinguish living beings from inorganic bodies, must be sought for in the *process* of *nutrition*, since it is in that process alone, that all living beings, and all living parts of a system, agree one with another.

This process consists in the transformation of the nutritive fluid into solids, which solids make up the frame-work of the system.

* With respect to the confusion of Hunter's notions concerning the coagulation of the blood, let the reader take the following specimen.

"I have now considered the circumstances under which the blood coagulates, and shown that none of them alone, nor all of them combined, induce the blood to coagulate. My opinion is, that it coagulates from an impression: that is, its fluidity under such circumstances being improper, or no longer necessary, it coagulates to answer now the necessary purpose of solidity. This power seems to be influenced in a way, in some degree similar to muscular action, though probably not entirely of that kind; for I have reason to believe, that blood has the power of action within itself, according to the stimulus of necessity; which necessity arises out of its situation."—*Op. cit.* chap. I. sect. ii.

In animals another result of this process is manifested in the resolution of portions of the solid materials into fluids. This result is caused by the influence of oxygen taken into the system by the respiratory apparatus.

When fluids are transformed into solids, or solids into fluids, the effects must be due to one of two causes. 1. The addition or loss of caloric; or 2; to a chemical change in the constitution of the substance which undergoes the mutation.

The first of these causes we must, for obvious reasons, reject at once, when applied to the explanation of vital phenomena.

It is admitted by all that a chemical change occurs, but the *cause* of this change is the subject of dispute.

The real distinction between the two sects of physiologists must be kept in mind. One sect attributes the change to a force or principle distinct from chemical forces—a force which is capable of controlling chemical forces—a force which may exist apart from the substances composing the body. The other sect attributes the transformation entirely to chemical forces.

At page 198 of the American Edition of Liebig's Animal Chemistry, it is said, that "there is nothing to prevent us from considering the vital force as a peculiar property, which is possessed by certain material bodies, and becomes sensible when their elementary particles are combined in a certain arrangement or form."

Upon this Mr. Ancell makes the following remarks.*

"In this passage it is perfectly clear that matter is regarded as being endowed with vital properties totally apart from organization; that is to say, the oxygen of the air, the carbon, hydrogen, and azote of food, and other chemical elements, have *vital* as well as *chemical* properties, of which the former do not become manifest, but remain occult, until such elements have assumed a certain arrangement or form.

"This notion in philosophy must be familiar to every reader. It is as old as Orpheus. It constituted a part of the doctrine of the ancient pantheists and naturalists. Saying nothing about

* London Lancet, vol. I. 1842–3. No. I.

the nature of the cause, the principle of life was regarded as inherent in all matter; when new matter becomes assimilated by an organic being, its vital principle was said to become manifest; when organized beings die, the matter is dispersed, still with its vital principle, which becomes occult."

Before taking notice of the peculiar notions expressed by Mr. Ancell, I must respectfully dissent from his interpretation of the passage in Liebig.

If it be remembered that the word *force* does and can mean nothing more than the manifestation of activity of substances in the production of change, it will be seen that the above passage, and almost every other in Liebig's work, may be made to assume an entirely different meaning from that attributed to him by Mr. Ancell.

If the *vital force* mean merely the manifestations of activity developed by material substances under *peculiar* circumstances, then the term as used by Liebig is just, and is strictly analogous to *force* used with other qualifications,—such as *force of elasticity*, *force of cohesion*, etc. In no way does the passage quoted assert the existence of a force apart from the substances which display the phenomena; or, that the oxygen of the air, etc., have *vital* as well as *chemical* properties. *Vital force* is a comprehensive term including many separate forces, all of which, however, in their essence are chemical. The very paragraph which immediately precedes the one quoted will prove this.

"As the manifestations of chemical forces (the momentum of force in a chemical compound) seem to depend on a certain order in which the elementary particles are united together, so experience tells us, that the vital phenomena are inseparable from matter; that the manifestations of the vital force in a living part are determined by a certain form of that part, and by a certain arrangement of its elementary particles. If we destroy the form, or alter the composition of the organ, all manifestations of vitality disappear."*

* Animal Chemistry. Webster's Amer. Edition, p. 198.

Than these words nothing can be more clear or more decisive. Other extracts may be brought forward.

"It must be admitted here, that all these conclusions" (i. e. all those deduced in the first part of his work) "will lose their force and significance, if it can be proved that the cause of vital activity has, in its manifestations, nothing in common with other known causes which produce motion or change of form and structure in matter."*

Again:—"In the processes of nutrition and reproduction, we perceive the passage of matter from the state of motion to that of rest (static equilibrium;) under the influence of the nervous system, this matter enters again into a state of motion. The ultimate causes of these different conditions of the vital force are *chemical* forces."†

Again:—"We should not permit ouselves to be withheld by the idea of a *vital principle*, from considering in a chemical point of view the process of the transformation of the food, and its assimilation by the various organs. This is the more necessary, as the views hitherto held, have produced no results, and are quite incapable of useful application."‡

And again:—"We are able to form in our laboratories formic acid, oxalic acid, urea, and crystalline substances existing in the liquid of the allantois of the cow, all products, it is said, of the vital principle. We see, therefore, that this mysterious principle has many relations in common with chemical forces, and that the latter can indeed replace it. What these relations are, it remains for physiologists to investigate. Truly it would be extraordinary if this vital principle, which uses every thing for its own purposes, had allotted no share to chemical forces, which stand so freely at its disposal. We shall obtain that which is attainable in a rational inquiry into nature, if we separate the actions belonging to chemical powers from those which are subordinate to other influences. But the expression 'vital

* Animal Chemistry. Amer. Edit., p. 185.

† Op. cit. p. 9.

‡ Agricultural Chemistry, 3rd Amer. Edit., p. 73.

principle' must in the mean time be considered as of equal value with the terms *specific* or *dynamic* in medicine: every thing is specific which we cannot explain, and dynamic is the explanation of all which we do not understand; the terms having been invented merely for the purpose of concealing ignorance by the application of learned epithets."*

It were indeed to be wished that Liebig had so expressed himself as not to be subject to misapprehension. But this he has not done, for several passages of his works seem to be in direct opposition to those above quoted. For instance, at page 394, Agricultural Chemistry, he says:—" The equilibrium in the chemical attractions of the constituents of the food is disturbed by the vital principle, as we know it may be by many other causes. But the union of its elements, so as to produce new combinations and forms, indicates the presence of a peculiar mode of attraction, and the existence of a power distinct from all other powers of nature; namely, the vital principle." We may, it is true, even in this place, interpret the words " vital principle" to mean the operation of material substances existing under peculiar circumstances, and *therefore* distinct from all other powers of nature; but the following will not admit of such an interpretation:—"We know not how a certain something, invisible and imponderable in itself, (heat,) gives to certain bodies the power of exerting an enormous pressure on surrounding objects; we know not even how this something is produced where we burn wood or coals.

"So is it with the vital force, and with the phonomena exhibited by living bodies. The cause of these phenomena is not chemical force;† it is not electricity, nor magnetism; it is a force which has certain properties in common with all causes of motion and of change in form and structure in material substances. It is a peculiar force, because it exhibits manifestations which are found in no other known force.‡

* Agricultural Chemistry, p. 75.

† This is direct contradiction with what has been aready quoted from page 9 of his Animal Chemistry.

‡ Animal Chemistry, p. 221.

In another place, he says, that "our notion of life involves something more than mere reproduction, namely, the idea of an active power exercised *by virtue of a definite form*, and production and generation *in a definite* form. By chemical agency we can produce the constituents of muscular fibre, skin, and hair; but we can form by their means no organized tissue, no organic cell."*

But assuredly these "organized tissues," these "organic cells" are themselves consequences or results of foregoing actions—excited among the particles of matter existing under peculiar circumstances. Production and generation *in a definite* form are also the necessary consequences of those circumstances—in other words, of the peculiar forces in action.

To return to Mr. Ancell. If we admit that the vital properties only become manifest when the substances which manifest them "have assumed a certain arrangement or form," it is obvious, that those properties are owing to that arrangement or form, or in other words, to the co-existence of certain substances under peculiar relations. For a property, as before shown, is only a mode of action in the bodies which manifest it. How then can "matter be regarded as being endowed with vital properties totally apart from organization?"

But it is said that the vital principle is inherent in all matter; that under certain circumstances it becomes manifest,—under others, occult. And, moreover, it is asserted that matter has *vital* as well as *chemical* properties. But wherein do these vital properties differ from the chemical? The two great vital properties, as laid down by authors, are contractility and sensibility. But the latter is not a property of plants, and, therefore, not essential to vitality. Contraction consists simply in a closer approximation of the particles which compose the substance that contracts;—the effect of external causes influencing the limits of corpuscular attraction. Whatever may be said of sensibility, assuredly contractility cannot reside in an atom; it

* Agricultural Chemistry, p. 392.

is, therefore, dependent on corpuscular arrangement and chemical constitution.

If the vital principle be inherent in all matter, then, it is similar to any other force; that is, it is a mere *modus operandi* of bodies when these bodies exist under certain circumstances. Not a thing *apart* from the bodies which manifest it;—not a thing *infused into*, or *superadded* to matter at the moment it becomes a part of the living being, and which may again leave the matter into which it has been infused. As well might we contend that elasticity is a thing that can exist apart from the steel spring which manifests it, as to assert that the vital force can exist apart from the substances which develope vital phenomena.

Force, or the capability of producing change, is certainly inherent in all bodies, for we cannot conceive of any body in nature, without at the same time conceiving of certain effects which that body may produce:—power, in short, is an essential element in our notions of matter. But when we make distinctions in philosophy we must have good reasons for so doing,—we must show that there is a real difference in the *modus operandi* and in the effects produced. This has not been done by those who assert the independent existence of a vital principle.

The assertion that a "vital principle" exists in all matter, at certain times, manifest at others, occult, which principle is distinct from all the other powers of nature, is a *petitio principii*, resting on assertion merely, not proof. It arises from a dim and vague perception of the great mystery of the universe.

The assumption is also a virtual abandonment of the doctrine of the vitalists; since they contend that the vital force (or life) is something superadded to brute matter, and which, therefore, may exist apart from the substances exhibiting vital phenomena.

APPENDIX, NO. III.

PART I.

PART I.

ABSORPTION.

I COMMENCE this subject with a narrative of, and an examination into, the causes of certain phenomena termed by Dutrochet *Endosmose* and *Exosmose*. To accomplish this, I cannot do better than translate his first experiment.

"I took," says he, "the cæcum of a chicken, and after having well cleansed the inside by injections of pure water, I half filled it with milk, and then closed the entrance with a ligature. I then plunged the cæcum into a vase full of rain water: it weighed, together with the milk, 196 grains. Twenty-four hours afterwards I took it from the water, and having weighed it, I found its weight to be 269 grains; showing a gain of 73 grains from the water introduced. I replaced the cæcum in the water, which I took care to renew, night and morning. Twelve hours afterwards, I found it weighed 313 grains. Thus in the space of thirty-six hours, the cæcum had introduced into its cavity 107 grains of water, and had become very turgid. From this moment, the weight of the intestine continually diminished: it lost its turgid condition, and collapse of the sides took place. Thirty-six hours after the commencement of this diminution in weight, the cæcum weighed but 259 grains: it had lost 54 grains of the water previously introduced. Foreseeing that this diminution would continue, I put an end to the experi-

ment; I opened the cæcum and found it filled with coagulated and putrid milk. The temperature during the experiment, ranged between 72° and 77° F. Having cleansed the interior of the cæcum by injections of pure water, I again half filled it with fresh milk, and placed it as before in water. Twenty-four hours afterwards I found its weight increased 21 grains. From this period, the weight of the cæcum progressively diminished. I opened it twenty-four hours after this, and found the milk decomposed and putrid."*

We observe in this experiment that water traversed an organic membrane to join the milk confined therein. To this phenomenon, Dutrochet gave the name of "Endosmose,"—from ενδον within, and ωσμος impulsion—an impulsion inwardly.

Reversing the experiment related above, but using a solution of gum-arabic instead of milk, *i. e.*, placing the water in the cæcum, and dipping this into a solution of gum, he found that a reverse action took place,—the water left the cæcum and joined the exterior solution. To this phenomenon, he gave the name of "Exosmose,"—from εξ without, and ωσμος impulsion—an impulsion outwardly.

But continuing his experiments, he found that rarely—perhaps, never, were these phenomena isolated, that endosmose did not alone occur in one experiment, and exosmose alone in another, but that they both occurred at the same time. If the exterior liquid entered the cæcum, so did the interior liquid come through the cæcum outwardly. By using liquids which may be tested by chemical agents, this fact is put beyond question. For instance, if we put a solution of salt and water into a cæcum and then plunge it into pure water, rapid endosmose will take place;—the cæcum after a time will swell out; but if we let fall a few drops of nitrate of silver into the exterior water, the presence of the salt will be instantly manifested.

Both the pure water and the solution of salt have then, traversed the membrane. But as the water has accumulated on one side, it is plain, that the two liquids have penetrated the

* L'agent immédiat. du Movement Vital, p. 116.

membrane at unequal rates:—the water, *plus*;—the salt solution, *minus*.

Endosmose and exosmose simply denote then, certain phenomena which are evident to the senses. They are not the names of newly discovered *powers*, as some have supposed, but of newly discovered *facts*, for an explication of which we must go to the general principles of science.

Dutrochet made similar experiments with different substances. He found that milk, albumen, gum-arabic solutions, syrups, alkaline solutions, etc., produced endosmose, if the cæca were placed in water; that on the contrary exosmose was the effect, if things were reversed, so that water occupies the interior of the cæcum. Diluted alcohol also produced exosmose with water. He found farther, that whenever the interior liquid was changed in its condition by putrefaction, etc., exosmose generally occurred if there had been previously endosmose.

Finally, he discovered that many porous solids such as freestone, sand-stone, carbonate of lime, white marble, sulphate of lime, etc., produced no effect upon those substances, with which an animal produced rapid endosmose.—On the other hand, he found that some other porous inorganic solids, as thin pieces of slate and baked clay produced effects equal to those of animal membranes.

Pursuing his experiments, Dutrochet attempted to discover the *rate* and *force* of endosmose.

To measure the *rate* he employed an instrument which he called an "Endosmometer." It is a very simple affair, being nothing more than a glass tube, open at one end and enlarged with a funnel-like mouth at the other, and over which is placed the membrane tightly secured by a ligature. Into the wide end (the reservoir) was placed the liquid, (the subject of experiment) and its rise or fall in the tube denoted the endosmose or exosmose. To the tube was attached a scale, each degree of which was the tenth of an inch.

The subjects of his experiments were syrups of different densities, which being introduced, the endosmometer was put in water. By examining the effects at intervals of an hour and a

half, he ascertained this law; "that the rate of endosmose was proportional to the difference in density, between water and each of the solutions employed." For instance, in the solutions the mean densities of which were, respectively 1·080, 1·141, and 1·222, the ascension in one and a half hours was for the first, nineteen and a half degrees; for the second, thirty-four; and for the third, fifty-three. Now the numbers expressing the different densities are to *each other*, nearly as 19½, 20·5, 22; which is far from the truth. But if we take the difference between the mean densities of each of these solutions, and water (which is one,) we shall have 0·080, 0·141, 0·222, which are to each other, as 19½, 34, 54; a result, which, making allowance for inaccuracies incidental to all experiments, is so accurate, as to leave no doubt concerning the truth of the principle.

These facts are extremely interesting, for they lead us to the causes of endosmose and exosmose. When a piece of salt is thrown into water the reciprocal actions of the two substances diminish in a steadily declining ratio. As the water ceases to take up the salt, so does the salt loose its affinity for water. Now you will see hereafter that the results obtained by Dutrochet in these experiments, are precisely of the same kind—dependent on the like causes, and as Dr. Mitchell has observed, such as might have been anticipated by calculation.

To ascertain the *force* of endosmose, he made use of the same instrument with this modification. It was bent twice upon itself, so as to form a syphon with a superior and inferior curvature. The limb attached to the scale of degrees is much smaller in diameter than the other limb and is also much longer, so that any little depression or rise in the shorter leg is instantly perceptible in the longer limb, by means of a column of mercury, which occupies the inferior curvature. The liquid is introduced through an opening in the superior curvature, and the instrument from the membrane to the mercury is entirely filled with it, so that no air exists in the shorter limb.

By observing the effects at intervals of twenty-four hours, he imagined that he found the same law to hold good here, which he discovered for the *rate* of endosmose; for the attitudes of the

column for the different solutions were proportional to the difference of mean density between each of those solutions and water. But the experiments, as you will see hereafter, do not give us the real power of the endosmose. To find that power, the whole weight should be laid on the membrane at once, for during the progress of the experiment, not only the interior liquid is changed in density and chemical constitution; but the intervening membrane itself is altered. The experiments then, do not show us the force of endosmose, but merely the time necessary for an equilibrium to be established between the two fluids. The time requisite for this will of course be different in each solution of different density, and the height to which the mercury is raised (provided the column be not of the maximum weight) will of course depend on this time.

The truth is, the *rate* and *power* of transmission are very different from the rate and power of endosmose—a fact Dutrochet was not aware of. The rate and power of the transmission may be exceedingly great, while endosmose is null. For example, suppose the two liquids penetrate the membrane at equal rates; it is plain there will be no endosmose or exosmose, *i. e.*, no accumulation on either side, yet the rapidity and power of the transmission may be enormous; for if we change the interior liquid for one of less penetrant powers, the force with which the exterior liquid penetrates will instantly appear.

But can this force be measured in any way? Dutrochet found in one of his experiments the column of mercury supported to be 45 inches high. He calculated that a syrup of sugar of 1·3 density, would produce an endosmose capable of raising a column of 127 inches of mercury, or the weight of 4½ atmospheres. But no membrane can support this weight. Dr. Mitchell found that the weight of a column higher than 63 inches broke the membrane, yet at the time this occurred "the weight of the column did not seem to very sensibly affect the rate of entrance." The determinate power, then, with which fluids traverse organic membranes, is unknown; we only know that it is enormously great.

To a reflecting mind there can be nothing more interesting

than these experiments of Dutrochet. The degree of attention they were likely to excite may be illustrated by a simple fact. "Hales lopped off the top of a young vine, and applying to the truncated extremity a glass tube, which closed round it, he found that the fluid in the tube rose to a height, which, taking into account the specific gravity of the fluid, was equivalent to a perpendicular column of water of more than 43 feet, and consequently, exerted a force of propulsion considerably greater than the pressure of an additional atmosphere.* This experiment of Hales was repeated with some modification by M. M. Mirbel and Chevreul, and they found the force of the sap impelled *à tergo*, sufficient to raise 29 inches of mercury above its level.† Now, the double curved endosmometer used by Dutrochet in his experiments to determine the force of endosmose, was the same apparatus employed by Mirbel and Chevreul, with this only exception, that in the former, an animal membrane replaced the truncated top of the vine. The effects, as we have seen, were nearly the same.

We pass now from the experiments of Dutrochet to those of Mitchell; the next in importance.

As Dutrochet had made his experiments on liquids, Mitchell turned his attention to the gases, and he found that like phenomena occurred in them.‡ When two gases were separated by a membrane, endosmose generally occurs on one side of the membrane, and exosmose on the other. Using a glass syphon with a single curvature, he measured the rate of transmission. His experiments on this point are more correct than those of Dutrochet, as he compared the different gases, not only with common air, but with each other. To do this, he tied over the wide mouth of the shorter limb of his syphon, a thin piece of gum-elastic, and secured it firmly. Into the longer limb he poured some clean mercury, so that a portion of common air was shut up in the shorter limb and in contact with the mem-

* Roget, B. Treatise, vol. 2. p. 26. Amer. Edit.

† Dutrochet, L'agent imméd., &c., p. 72.

‡ On the Penetrativeness of Gases. American Journal of the Med. Sciences, vol. 7.

brane. The funnel-like extremity was then introduced through a mercurial trough into the gas, (the subject of experiment) and the velocity of the penetration was measured by the time taken to elevate the mercurial column in the other limb to a given degree. The results were as follows:

"Ammonia transmitted in 1 minute as much in volume as sulphuretted hydrogen in $2\frac{1}{2}$ minutes, cyanogen $3\frac{1}{4}$, carbonic acid $5\frac{1}{2}$, nitrous oxide $6\frac{1}{2}$, arsenuretted hydrogen $27\frac{1}{2}$, olefiant gas 28,* hydrogen $37\frac{1}{2}$, oxygen 1 hour and 53 minutes, carbonic oxide 2 hours and 40 minutes. Nitrogen has a rate of penetration so low as to be difficult to ascertain, because there is no gas of a lower rate with which to compare it. Only by causing it to pass through a membrane by means of a column of mercury, is the fact of its transmission known. In that way the quantity being compared with that of carbonic acid, its rate was found to be about three hours and a quarter. This experiment, made but once, is not confidently relied on; but the rate of nitrogen is unquestionably less than that of carbonic oxide.

"Chlorine immediately altered the texture of the membrane, as did muriatic acid gas, sulphurous acid, nitric oxide, and some others, so that it was impossible to reach, for their rate of penetration, accurate results.

"In every case the movement of the gas through the membrane became progressively slower, until it totally ceased; and finally, but more slowly, the mixed gas returned, as indicated by the descent of the column of mercury. The retrogradation ceased only when the two columns came to equilibrium, or failing the possibility of that, when the mercury in the shorter limb had reached the membrane, through which mercury has not been found able to penetrate."†

In estimating the *force* no positive results were obtained. It was only ascertained to be extremely great "at the height of sixty-three inches," says Dr. Mitchell; "the membrane, though supported by cloth, could scarcely sustain the weight, and

* He afterwards ascertained that the rates of transmission for arsenuretted hydrogen and olefiant gas were exactly equal.

† Opus cit., p. 40.

would not bear any increase of weight. Although, therefore, at present, I do not know the limit of this power, I believe it will be found very much greater, because the power of the column which was tried did not, until a leak was sprung, seem to very sensibly affect the rate of entrance."

A reciprocal transmission occurs then, when two liquids or two gases are separated by a membrane. How are these phenomena to be explained?

Most persons are perhaps aware that Dutrochet attributed them to electricity. Adopting the theory of Dufay, he supposes the phenomena to be caused by two electric currents traversing the membrane at the same time. To establish this conjecture, he summoned to his aid the experiments of Porrst. This gentleman discovered that if water be separated by a piece of bladder, into two portions, and the positive pole be applied to one apartment and the negative to the other, the water will traverse the membrane so as to accumulate on the negative side. Dutrochet repeated these experiments with his endosmometer, and found endosmose took place on the side of the negative pole. Putting the negative pole into a solution of gum-arabic contained in the endosmometer, and the positive pole into the exterior water, he found the rapidity of the usual endosmose greatly enhanced. Moreover, alkalies were found to produce endosmose with water; and this he imagined a strong point of analogy, for it is well known that if a neutral salt be submitted to the action of the pile, the alkali is found at the negative pole and the acid at the positive. It was, therefore, important to prove that acids cause exosmose, i. e., a phenomenon the reverse of that produced by alkalies. Wishing to find this suspicion true, he did find it so: sulphuric acid in solution with water, poured into the endosmometer, he found produces exosmose; that is, left the endosmometer and mingled with the water. I may as well relate now that Dutrochet deceived himself in this. In his late work he makes the correction himself, for he found in a subsequent experiment, that if the endosmometer was supplied with water and then put into diluted sulphuric acid, exosmose of the water took place—that is, the

water traversed the membrane to unite with the acid solution. He, therefore, changed his opinion on this point, and fell into another error fully as great; for he concluded that the acid put a stop to the phenomena altogether, and hence he termed it an enemy (*un enemi*) of endosmose. This is not strictly true, as is proved by his own experiments; by those of Togno* and those of Mitchell. Both of the latter discovered that sulphuric acid sometimes produced endosmose, at others, exosmose, and sometimes neither; the cause of which variance will be explained hereafter.

Besides this, Dutrochet discovered that endosmose was more rapid, the higher the temperature. In comparative experiments, one of which was made at 41° F., and the other, at 88° F., thirteen grains of water were in one and a half hours introduced in the first case; and twenty-three grains in the second. Here he had another point of analogy; for Becquerel had proved that a rise in the temperature of two metals placed in contact, increased the intensity of the electric current.

Finally, when he placed albumen in the endosmometer and excited endosmose, by placing it in water, he found the albumen coagulated so as to form a false membrane on the side of the instrument. A similar effect is produced if we subject albumen to the action of the galvanic pile.

He, therefore, thought the points of analogy numerous and strong enough, to warrant his attributing these phenomena to a double current of electricity; which, acting as they do in the pile, produce an accumulation of fluids at the negative pole.

His theory then, was as follows:—

1. That endosmose is entirely the result of an electric current, passing from the positive pole (the zinc, or *less dense*) to the negative pole, (the copper, or the *more dense*;) so that the cæcum or endosmometer, is the same as a Leyden jar, the interior of which is occupied by electricity opposed to that which exists outwardly.

2. As the accumulation is always towards the negative pole,

* Amer. Journal of the Med. Sciences, vol. iv.

the cæcum will develope endosmose when the interior is negative, and exosmose when it is positive.

3. And these conditions will be brought about by the contact of different liquids. If the interior liquid be the denser, the interior of the cæcum will be negative, and *vice versa*. Hence endosmose is always on the side of the denser fluid.

4. But Dutrochet also discovered that if an empty cæcum be secured by a ligature and plunged into water, the liquid will gradually insinuate itself and accumulate in the inside. Here, there existed no denser fluid in the interior;—how then could he explain the phenomenon?

He had recourse to his old theory of elementary organization, according to which, the animal tissues are composed of numerous smaller vesicles agglutinated together and filled with organic substances more dense than water. Each of these little vesicles then, are small Leyden jars; and the membrane itself is nothing more than an immense number of these little jars in contact with each other. Therefore, when the membrane is plunged into water, the interior of each of these vesicles is negative, whilst the outside is positive. Now from the known laws of electricity, it follows that the hollow organ is itself a Leyden jar of larger size, but of the same kind as the smaller ones that make it up. The positive electricity which occupies the exterior of each of these little Leyden jars, must accumulate towards the exterior of the hollow organ, from the repulsion which negative electricity exercises on the positive; consequently, the interior of the hollow organ will be negative.* Hence the water must enter the cæcum and accumulate therein.

Such was the theory advanced by Dutrochet in his first work on this subject. It seems, however, to have been shaken, both by his own subsequent experiments, and the objections of others. From his second book I will translate the entire passage relating to this point. " Endosmose," says he, " is the immediate result of a difference in density, or more generally of *heterogenicity* in two liquids, which are separated by a permeable *active* parti-

* L'agent immédiat., etc., p. 140.

tion. This result from a difference in the density of two liquids, ought at first view to make us believe, that it is owing to an electrical action; but experiments in physics prove, or at least seem to prove, that no electricity results from the contact of two liquids of different density. M. Becquerel has proved that the contact of liquids on solid bodies does indeed produce electricity, but this effect is only proved for those liquids which produce a chemical action with the solids. Now, the contact of water and organic liquids at the two surfaces of an organic membrane, does not produce any electricity appreciable to the galvanometer, as I have assured myself by experiment. The cause of endosmose is then involved in much obscurity. I had sometime supposed this cause to be electricity, and I am yet inclined to believe so; but it is not sufficiently demonstrable. There exist, in favour of this opinion, the probabilities only, which I will now expose. I have cited in a preceding work, the experiment of M. Porret, who proves that the electric currents of the voltaic pile give an impulse to water, causing in it an ascending movement, when the currents are directed through an organic membrane, bathed on each side by the water. So that we can by these means, purely electric, produce an endosmose without heterogenicity of liquids. I put some distilled water into the reservoir of an endosmometer, which was itself plunged into distilled water. Plunging the negative wire of the voltaic pile into the tube, I placed it in contact with the interior water. I then placed the positive pole in contact with the exterior water. Very soon I saw the water mount in the tube and arrive at the superior opening. It run over, and did not cease to run, until the action of the pile was weakened. It results from these experiments that there exist *two* causes of endosmose; 1. Heterogenicity of liquids; 2. Electricity of the voltaic pile."*

Remark that Dutrochet now admits two causes in the production of endosmose;—heterogencity of liquids and electricity. He was forced to do this from his own experiments. In order to sustain the electrical theory, it was necessary to prove that

* Nouvelles Recherches, sur L'endosmose et L'exosmose, p. 31.

the accumulation of liquids always occurred on the side of the denser fluid. Now this is far from being true;—as the following facts will show.

If a small quantity of water be placed in a cæcum and then this latter be plunged into the same water from which it was taken, endosmose will be produced.*

2. Putrid milk, putrid albumen, etc., produce exosmose, yet they are denser than the water they conjoin with.†

3. Spirits of hartshorn mixed with water produces endosmose, though its specific gravity is less than that of the water which enters to combine with it.‡

4. Concentrated alcohol produces endosmose with water, if the membrane be an animal one.§

5. Sulphate of soda and muriate of soda in solution equally dense, produce endosmose with water, in the ratio of 44 to 3, "which result," says Dutrochet in the face of his own theory, "indicates that the sulphate of soda in producing endosmose, possesses far greater energy than the muriate, a quality which is owing to its chemical properties.||

These facts, taken from Dutrochet's works, are utterly irreconcileable with the electrical theory. Dr. Mitchell has added other objections.

6. Concentrated alcohol produces exosmose with water if the membrane be of *gum-elastic.*

7. Carbonic acid gas (the denser fluid) penetrates the membrane to unite with common air, with oxygen, and even with hydrogen.

8. He proved in opposition to the conclusions of Dutrochet, that the different sides of a membrane had a sensible effect on the rate of penetration. When the cuticular side of the human skin was exposed to carbonic acid gas, and the raw surface to common air, the carbonic acid entered more rapidly than when the experiment was reversed. The same effects occurred when a portion of the intestine was used;—the gas penetrated the mucous surface more rapidly than it did the serous surface.

* L'agent imméd., etc., p. 118. † Ibid., p. 116 et 124. ‡ Ibid., p. 150.
§ Ibid., p. 153. || Ibid., p. 154.

The truth is, the passage of a fluid through the membrane is altogether an affair between those substances. Endosmose occurs when the interior fluid can take up the exterior as fast as it is presented by the membrane, but at the same time does not penetrate the membrane so rapidly as the exterior; so that a dry sponge or oatmeal would answer the purpose equally as well as the interior solution of gum.

Besides these objections to the theory of Dutrochet, there is one still stronger: it is an hypothesis resting on an hypothesis. The theory of Dufay is itself very far from being established.

It is fashionable at the present day to attribute all unaccountable phenomena to the agency of electricity. It plays in modern philosophy much the same part that sympathy did of old. But it would be wiser if we waited until we know something positive concerning electricity itself. The researches of Becquerel, De la Rive, Pouillet, and Faraday go very far towards proving that electricity is not a primary cause in nature, but an effect of higher causes. They seem to establish the doctrine, that like the evolution of light and heat in combustion, this imponderable electric matter is only let loose during a play of chemical affinities; and is thus made evident to the senses;—in short, that these mysterious movements among the corpuscles of matter are *not caused* by the electricity developed; but that the electric matter is made manifest *in consequence* of those movements of combination and decomposition. So that had Dutrochet even discovered that the galvanometer was affected when two liquids of different density came in contact, it would not have established his theory.

Why an electric current produces an accumulation of water at the negative pole, as occurred in the experiments of Porret, Reuss, and Dutrochet, we do not know; nor will we be able to comprehend the cause until we know more concerning electricity itself. The late experiments of Mr. Faraday on the chemical effects of galvanism, give us strong hopes, that this subject ere the lapse of many years will be fully understood.

The phenomena of endosmose and exosmose cannot, then, be owing to electric currents.

Another theory which attributes the phenomena chiefly to capillary attraction, has been proposed by M. Poisson, a celebrated mathematician. As the note of Poisson is short I will translate it entire.

"Let us suppose that in a vase, we have two different liquids, A and B, separated from each other by a vertical partition, and that their respective heights are in the inverse ratio of their densities, so that, the points *a* and *b* at the surfaces of the partition, shall be in the same horizontal plane, and support equal and contrary pressures. Let us further conceive the partition to be pierced by one or many holes, the diameter of which are extremely small; or in other words, that it is traversed by one or a number of canals like *a b*, extremely small, perpendicular to the two surfaces, and which we may regard as being filled with air or any other fluid.

"If the substance of the partition exercise on each of these liquids an influence superior to the half of that which each liquid exercises on itself, the liquids will enter the canal *a b*, in the same way that each would rise above its level in a capillary tube of the same diameter and composed of the same material. Besides this, they will be forced in by the excess of pressure exercised at the extremities of the canal over the elasticity of the interior air. When the two liquids have entered *a b*, the air will be pressed in a contrary way by two forces, each of which will be equal to the original pressure, increased by the corresponding capillary force;—that is, (according to the well known theory of Laplace,) increased by a power proportional to double the action of the tube on the liquid; minus, the action of the liquid on itself. Should the capillary force be the same for both sides, the air after having undergone some compression, will remain at rest, but the least excess of force occurring at either end of the canal, will cause the air to escape from the opposite side, and the liquid subjected to the stronger capillary action, will completely fill the canal.

"Suppose this liquid to be A;—let us then consider the forces which will now act on the thread *a b*, formed by the liquid.

"At the extremity *a*, this thread of liquid will be subjected to the attraction of the exterior liquid A;—at the extremity *b*, it will be drawn the opposite way by the liquid B: now these two liquids being different, these attractions will be unequal; and we will now suppose the attraction of B for the liquid A, is superior to the attraction of A for its own molecules. As to the influence of the canal on the thread *a b*, it will be equal, and will be exercised in opposite ways at the two extremities; it will then, neither oppose the motion of the liquid in the canal, nor contribute to it; and the same will be the case in regard to the pressure exercised at *a* and *b*, by the exterior liquids; because by supposition, they are equal. Nevertheless, the action of the canal, and the pressure at each extremity, will prevent the thread from being broken, so that it will run uninterruptedly towards the side whither it is solicited by the greater attraction, or in other words, from *a* towards *b*. Hence, an elevation of the level of the liquid B will result; and in consequence, an excess of pressure at the extremity *b* of the canal *a b*. This elevation will continue until the difference of pressure on *a* and *b* becomes equal to that of the attractions exercised by the two liquids over the thread *a b;* which will take place so much the sooner, the greater number of holes there are in the partition.

"Now let us examine what would take place, were the partition not a single one, but formed of two others, different in their nature, but exactly placed in juxta-position; neither of which would exercise any influence over one of the liquids, (over B, for example,) and one of which only would act on the other liquid.

"In this case, the liquid B will be retained in its own part of the vase by the reciprocal actions of its own molecules; it will not penetrate the canal *a b* in the same way that mercury will not penetrate a capillary hole made in the tube of the barometer. The same thing will happen with regard to A, when that side of the partition which has no influence over it, is turned towards it; and when such is the case, whatever number of capillary holes the partition may possess, the two liquids will remain

apart and keep their primitive levels. But if we revolve the partition so that the side which acts on A, shall be in contact with that liquid, A will penetrate the canal *a b*, by virtue of capillary action. The rapidity, which the liquid subjected to this force, acquires while in motion, may even cause it to pass the point where the partition changes its nature, and even reach the extremity where the canal ends in B; so that the liquid A shall fill entirely the canal *a b*, just as happens in the case first supposed. Such being the case, if we farther suppose the attraction of B for A, continues to be superior to that which A exercises over itself, the liquid thread *a b*, will flow into the cavity occupied by the liquid B; the level of which will be raised until the excess of pressure which will result therefrom on the point *b*, shall balance the difference of the attractions exercised by the two liquids at *a*, and *b*.

"I have written this note," continues M. Poisson, "on account of the phenomena relative to absorption, exercised by vegetable and animal membranes, concerning which, M. M. Dutrochet and Magendie entertained the Academy in the session of November last. I do not pretend, however, to assign them a cause exclusive of every other, nor to give a sufficient explication of them. My aim is merely to show, that effects which have at least a great resemblance to these important phenomena, can be produced by capillary action, conjoined with a difference in the affinities of heterogeneous substances, and that without the aid of electricity either in repose or in motion."*

To these ingenious observations of M. Poisson, Dutrochet made objections in his last work;—the principal of which are as follows:—

1st. That according to the explication given, the sole influence of the interposing membrane would be derived from its capillarity; but we have seen that all porous substances are very far from affording the same phenomena. Sand-stone, free-stone, porous carbonate of lime, sulphate of lime, (both calcareous and crystallized) produce no such effects, however thin they may be.

* Journal de Physiologie par Majendie, tom. vi. p. 361.

2. The force of endosmose is extraordinarily great; capable indeed of breaking the stoutest membranes;—we cannot grant such power to mere capillary attraction.

3. The explication given by Poisson will at the best, only account for the endosmose on one side, and exosmose *as a consequence*, on the other. If the liquid A flows into the cavity occupied by B, this last cannot at the same time penetrate into the cavity occupied by A, yet we have seen that in every case of endosmose, each of the liquids penetrates the membranes at the same time, and respectively mingles with the fluid on the other side.

It is indeed true that the facts war with the explication given by M. Poisson—nevertheless, we believe he is perfectly correct in his fundamental positions. We shall, therefore, go on to show, that the phenomena of endosmose and exosmose, are mere modes of a general fact in physics:—the attraction of matter to matter. In doing this, we shall only extend the explication given by Drs. Mitchell and Turner.*

All know the general fact, that matter is attracted by other matter in its vicinity. The collection of dust on the smooth surface of a mirror; the coalescing of two globules of mercury;—the formation of a shot during the fall of melted lead; the approach of a cork to the sides of a basin; the divergence of a bullet from the perpendicular when suspended from a high cliff, or in other words, its tendency to approach the sides of the mountain in opposition to gravity, are but a few instances selected out of many thousands.

If we suspend a sheet of tin or silver on the hydrostatic balance, and placing weights in the opposite scale, bring it to an exact equilibrium; we shall find, if we bring the sheet of metal in contact with mercury or any other liquid, that it will take a considerable addition of weight to separate them again, and when we have done so, we shall find the weight in the scale much preponderating over the sheet of metal. This experiment proves two things. 1st. The existence of attraction

* Elements of Chemistry, p. 614, Amer. ed. of 1835.

between the metal and the liquid. 2d. The attraction of the molecules of the liquid for each other: for did not this latter force exist, it is plain, that to remove the metal from the surface of the liquid, it would only be necessary to put into the opposite scale a weight equal to that of the liquid removed, when the two are torn apart. This however is not the case; the weight required is much greater; and besides, when mercury is used in the experiment, none is removed with the solid body.

Now it is to be particularly observed that the attraction of bodies for each other, is by no means of equal force. Thus the attraction of alcohol for water is greater than that of oil, the attraction of oil for glass is greater than that of water; the attractive particles of oil for each other is greater than the attraction of the same for water.

If when a solid and a liquid come in contact, the attraction of the solid particles for each other be greater than their attraction for the liquid, the solid will remain unchanged. If on the other hand, the attraction of the solid and liquid particles be greater than that of the solid particles for each other, the cohesion is destroyed, and the two substances thoroughly intermingle: We have a case of simple solution. Hence the different solubility of different substances.*

From these principles it follows, that if the same liquid be put into three or more cups of different kinds of matter, there will, in all probability, occur different results. For if between one of the cups and the liquid the attraction be greater than the attraction of the liquid particles for each other, the liquid will be attracted to the solid, and its density diminished. If the attraction be equal on both sides, the liquid will present a plane surface, and its density will remain unchanged. If the attraction

* "The solubility of salts is in direct ratio with their affinity for water, and in inverse ratio with their cohesion. One salt may have a greater affinity for water than another, and yet be less soluble; an effect which may be produced by the cohesive power of the salt which has a stronger attraction for water, being greater than that of the salt which has a less powerful affinity for that liquid." —*Dr. Turner, Elem. of Chemistry*, p. 423, Am. ed. 1835.

of the liquid particles for each other be greater than for the solid, its density will be increased by the cohesive power bringing them close together.

To put this subject in another point of view. Let us suppose that from a body of water a spherical portion was suddenly removed into absolute space, and, therefore, uninfluenced by any other substance, but at the same time retaining its temperature. What would be the consequence? The density of the water would unquestionably be increased: it would contract in dimensions. It would contract, because a force tending to draw the outer particles of the sphere away from the centre, has been removed; they are no longer under the control of contiguous particles—they, therefore, and all the rest, tend towards the centre.

The increase or diminution of density in liquids from these causes are usually so slight that it escapes observation, but it is rendered obvious in capillary attraction.

When an insoluble substance comes in contact with a liquid, one of three things must occur. 1st. The particles of the liquid will be attracted with a greater force towards the solid than towards each other; or 2ndly, their attractions for each other and for the solid will be equal; or 3rdly, their attraction for each other will be greater than for the solid. All these cases occur in our experiments with capillary tubes.

If the liquid particles have a greater attraction for the solid than for each other, there will be a rise of liquid in the tube: this occurs when glass capillary tubes are dipped into water. If the forces of attraction be equal on both sides, the liquid in the tube will be on a level with that outside:—this takes place when a perfectly *dry* tube is plunged into mercury. If, on the other hand, the liquid particles possess a greater force of attraction for each other than for the solid, the interior liquid will be depressed:—this occurs when a glass tube is moistened with oil and then plunged into water.

The rise of the fluid in the first case, is caused by the liquid particles in immediate contact with the tube, tending to separate from those adjoining. The particles continue to be drawn

towards the higher molecules of the glass, and the ascension will go on until the weight of the column counterbalances the force of the reciprocal attraction.

The first effect is confined to the molecules of the liquid in immediate contact with the tube, but as those molecules attract those adjoining with less force, and those again others, it is plain, that the influence of gravity will be felt more and more towards the centre where it is greatest. Hence the *concave* surface formed.

The second case (that of a plane surface) requires no explanation.

In the third case a convex surface is formed, and from causes precisely opposite those which form the concave. In this case a force keeping the liquid molecules apart, is *removed* at the sides of the tube. Hence the lowermost molecules in the tube approach closer to those below, and so on, throughout the tube and the containing vessel. There is an increase of density, not only in the tube, but throughout the entire liquid. As the particles of liquids all tend towards a common centre when left uncontrolled by outward forces, a *convex* surface is necessarily formed.

If we now turn our attention to liquids, we shall find among them the same phenomena. If when mixed together one has a greater attraction for itself than it has for the other, they will not mingle together; an example of this occurs in the mixture of oil and water. If the attractions on both sides be equal, we shall have a diffusion of one liquid in the other, more or less universal, according to external agencies, such as specific gravity, mechanical motion, etc. If, on the other hand, the attractions of the two liquids be greater for each other than for themselves respectively, and if these attractive forces be sufficient to overcome a difference in specific gravity, etc., we shall have a general admixture of particles;—a uniform infiltration of one liquid through the substance of the other. An example occurs in the mixture of alcohol and water.

The same principle is at work with respect to the gases. An example is before us in the atmosphere, the components of

which, though of different specific gravity, are found to be every where the same. Mr. Dalton discovered that if a communication was made between two cylindrical vessels, the upper of which contained hydrogen, and the lower carbonic acid gas, that in the course of a few hours, in spite of the greater specific gravity of the lower gas, a general admixture would ensue. To explain this phenomenon, he made the extreme supposition, that though the particles of the same gas repel each other, they exist as a vacuum to those of another kind. In this explication, the whole weight of analogy is thrown aside and discarded. Mr. Dalton knew very well the general fact, that matter attracts matter; he knew well enough, that a light body placed on the surface of a basin of water, would approach the solid sides, though when it reached these no chemical union took place; he knew all this, yet because the carbonic acid gas formed no chemical compound with the hydrogen, he declared that the phenomenon was not owing to affinity, but to the hypothetical causes proposed by himself. But the phenomenon is evidently of the same kind as those mentioned above; and is explicable on the same principles. It would indeed be an interesting question to determine, why these substances do not unite in chemical combinations; but it is a question to solve not for gases only, but for *all* bodies which attract each other, and yet after coming in contact retain their original form and composition.* For instance, it is a question implicating all cases of solution; for when a salt is dissolved in water, we cannot grant, that a chemical union has taken place; in other words, that the elements of the salt have combined with the oxygen and hydrogen of the water.

That Mr. Dalton's explication is unsound, is sufficiently proved by the experiments of Dutrochet and Mitchell. We have seen that gases penetrate animal membrane with immense force—a force unknown, because no membrane is capable of supporting it. Now, we know that these phenomena cannot be owing to the mere diffusive power of gases, which

* This question has been explained in a foregoing chapter. See chap. 3rd.

result from the self-repellent properties of their molecules. Under ordinary circumstances, a thin fragile stratum of glass is sufficient to control all this power of repulsion.

Liquids again mingle in solution with gases; and conversely, gases with liquids. Spontaneous evaporation, the diffusion of liquid odours in a still atmosphere, etc., offer themselves as examples of the first; whilst instances of the second case are found in the condensation of ammoniacal gas, muriatic acid gas, etc., etc., in water.

Finally, gases are attracted and held stationary by solid bodies; a most obvious instance occurs in the absorption of gases by charcoal. To this phenomenon I would call particular attention, for it is identical in principle with those of endosmose and exosmose.

We have seen that animal membranes transmit in a given time more of one gas than of another:—as much ammonia was transmitted in one minute, as there was of carbonic oxide in two hours and forty minutes. Now we shall see a similar difference in the absorbing powers of charcoal with respect to different gases. Saussure found that charcoal prepared from box wood, absorbs in twenty-four or thirty-six hours of

Ammoniacal gas . .	90	times its volume,
Muriatic acid . . .	85	"
Sulphurous acid . .	65	"
Sulphuretted hydrogen .	55	"
Nitrous oxide . . .	40	"
Carbonic acid . . .	35	"
Olefiant gas . . .	35	"
Carbonic oxide . .	9.42	"
Oxygen . . .	9.25	"
Nitrogen . . .	7.5	"
Hydrogen . . .	1.75	"*

What then is the cause of this difference in the quantities absorbed? There seems to be very little relation between them and the chemical affinities of the respective substances for car-

* Turner's Elem. of Chemistry, p. 185, Am. ed., 1835.

bon, as oxygen which has a strong affinity for carbon, stands very low in the scale. What explication then is to be given of those facts?

Let us first settle what is meant by the word gas. A gas is a substance held in solution by caloric.* This infiltration of caloric among its particles, is the cause of the repulsion they exert on each other. So, increase the caloric, and you increase the repulsive power; abstract the caloric, and you suffer the

* "Spontaneous evaporation has been long a subject of interest to the philosopher, and has not hitherto admitted of adequate explanation. Now we perceive, that in elevating moisture into the atmosphere, a very powerful agent is at work, one capable of subverting the cohesion even of solids, and of producing the continued infiltration of the atmosphere. Heat being also capable of destroying the attraction of aggregation, augments evaporation and interstitial infiltration. On this, (I speak it hesitatingly) depends the power of steam. Caloric penetrates gases as they do each other, and escapes from them in exactly the same manner when substances which contain less of it, invite its penetrant power in a new direction. Thus, for illustration, carbonic acid penetrates common air, and, so far as we know, will expand it, if constantly supplied, to an amount of power not yet measured. But so soon as another gas or penetrable substance is presented, it begins to withdraw from the air and to penetrate that. The hollow intestine used in one of our experiments was powerfully inflated by its entrance, and yet as rapidly collapsed when the gas was invited outwards by the pressure of another gas on its exterior. The resemblance of phenomena does not end here. Each penetrates different substances with different degrees of facility, and the *quality of the surface* is often to both as influential as the character of the substance which affords it. The *fact*, the *force*, the *enlargement of bulk*, the *penetrativeness varying usually with the substance and surface to be acted on, being however uniform relative to all gases*, the *constantly diminishing rate of progression*, the *issuing out again when invited by new substances, or by a vacuum, or when mechanical compression is applied*, all afford evidence of analogy as perfect as is perhaps ever offered to the view of physiology.

"We are struck with its resemblance *to water* in one respect. Highly concentrated caloric invites the penetration of all liquids, and perhaps of all solids, and thus, while held in solution by it, they obtain a penetrativeness themselves which does not naturally belong to them, and are elevated into the atmosphere in spite of specific gravity, however high, or of atomic weight, however considerable. Some facts, not yet sufficiently studied, lead me to the perhaps hasty conjecture, that even the *decomposing* influence of caloric is owing to this power. Water exercises it in that way in some cases, such as that of acetate of lead."—*Mitchell, Op. cit.* p. 59.

attraction of the molecules of the gas to be made evident; they will take the liquid or solid form, which only differ from the gaseous in respect that the particles are in closer contact.

Now the caloric may be abstracted in various ways, among others, by pressure.

We have shown that the phenomena presented by liquids in the capillary tubes, depend on the attraction of the liquid for itself and for the substance of the tube,—as these vary so will the phenomena. A like difference occurs in the liquefaction of gases by pressure: the force necessary, will vary according to their attraction for themselves, and their affinities for caloric. Hence ammoniacal gas is easily condensed into a liquid; but no force has yet succeeded with oxygen, hydrogen, and nitrogen.

But what is the modus operandi of pressure? The rise of water in a glass capillary tube is a sufficient proof that these bodies attract each other, yet no solution takes place, evidently because the molecules of the glass have more attraction for each other than for the water. This is expressed in philosophical language, by the term "Cohesion." Now the liquefaction of gases by pressure is caused by nothing more than the attraction of cohesion increased by mechanical agency. We lend this force to substances which do not naturally possess it. Therefore, it follows that if we could substitute for pressure any other power tending to increase the attraction of cohesion we should produce the same effects. Now that such a power is exerted by the charcoal over the gas which it absorbs, the foregoing table will evidence. By referring to it, it will be perceived that the liquefiable gases stand highest in the scale. But it will also be observed that the quantities absorbed by charcoal are not strictly in the ratio of the forces required to condense them;—the probable causes of which will be mentioned presently.

What then is this power? The very same that causes the rise of water in a capillary tube; the reciprocal attractions between the different gases and the charcoal; for the lump of charcoal is permeated in every direction by tubes more or less

large. Molecule after molecule of gas is then seized and retained by this porous substance; the particles thereby are brought in closer contact, and a true liquefaction of many of them occurs. The relative quantity of gases absorbed will then depend on, 1st. The reciprocal attraction of each gas and the charcoal; 2d. On the attraction of each gas for itself; 3d. On the affinity of each gas for caloric. If the first two conditions be superior to the third, a larger quantity of the gas will be absorbed. This is probably the case with muriatic acid gas, to liquefy which it takes a pressure of forty atmospheres; whilst to liquefy sulphurous acid gas two atmospheres only are necessary. Yet eighty-five times the volume of the first is absorbed by charcoal, and only sixty-five of the latter. This must occur from the paramount attraction of the muriatic acid gas for the charcoal; probably from the same affinities that produce chloride of hydro-carbon, which is only prevented being formed by the paramount cohesive attraction exerted among the molecules of the charcoal.

It follows from this explanation that we ought to diminish to a great extent, the absorbing power of charcoal by destroying its capillarity; and this is true, for if it be pulverized, the power of absorbing gases is almost destroyed.

It follows too, that a greater quantity of vapour should be absorbed than of gas; and of a liquid than of vapour, which is also the fact.

Another corollary is, that we ought to prevent absorption by increasing the quantity of caloric in the charcoal. If we add more heat, the molecules of the liquefied gas ought to be taken up in solution, just as when we add more water, the particles of salt which had fallen to the bottom of the vessel, would be taken up and dissolved. Now this again accords with experiment;—caloric applied to the charcoal liberates the confined gas.

The connexion that exists between the liquefaction of gases by pressure, the absorption of them by charcoal and other porous solids, and endosmose and exosmose, struck Dr. Mitchell, and he has given the following table to illustrate it.

Liquefaction of Gases by pressure.		Rates of penetration by Gases.		Quantity of Gases absorbed by charcoal.	
Gases.	Pres. in Atmospheres	Gases.	Minutes.	Gases.	Volumes.
Cyanogen	4	Ammonia	1	Ammonia	90
Ammonia	6½	Sulph. Hydrogen	2½	Sulph. Hydrogen	55
Sulph. Hydrogen	17	Cyanogen	3¼		
Carbonic Acid	42	Carbonic Acid	5½	Nitrous Oxide	40
Nitrous Oxide	52	Nitrous Oxide	6½	Carbonic Acid	35
		Olefiant	28	Olefiant	35
		Hydrogen	37½	Carbonic Oxide	9.42
		Oxygen	113	Oxygen	9.25
		Carbonic Oxide	160	Nitrogen	7 5
		Nitrogen	195	Hydrogen	1.75

"Making," continues Dr. Mitchell, "the usual allowance for the inaccuracy of different experiments, there seems a probability of some relation not yet fully developed between the mechanical condensibility of the gases and their absorption by charcoal and other porous bodies, and between the latter property and the transmissibility through membranes."*

It follows then, from the examination which we now conclude, that the rise of liquids in capillary tubes, the solution of a salt in water, the intimate mixture of two fluids, (gases or liquids) and the absorption of fluids by solid bodies, are mere modes of the same phenomenon.

We will now proceed and apply the foregoing observations to the phenomena of endosmose and exosmose.

It is necessary, however, to make beforehand a few remarks on the constitution of the organic solids. All these bodies, vegetable as well as animal, are *porous;* and this porosity is not confined to pores visible to the eye or microscope, but exists to a far greater extent. Fluids pass through membranes in which we shall in vain endeavour with the most powerful microscopes to detect any visible opening. They pass in truth, between the molecules of the solids, just as in a case of solution, the particles of the salt penetrate intermolecularly the substance of the liquid. In fact, during life all the organic solids are infiltrated with liquids; they make a component part of the solids, and when withdrawn, the solids lose weight and are incapable of performing their functions.

* Amer. Journ. of Med. Sciences, vol. 7. p. 212.

It should not appear strange that the organic solids are so constituted as to permit fluids to pass through their intermolecular spaces, for they hold a middle rank between perfect solidity and fluidity; and that solid particles interpenetrate liquids, as in cases of solution, is notorious.

We know that heat penetrates all bodies, and that light penetrates a great many. To do so they must pass through the intermolecular spaces of bodies, for as all bodies expand by heat, and contract when robbed of it, the particles of no body on earth can be in actual contact. But bodies, as the metals, glass, and so on, are not penetrable to liquids. This is owing to their great density—the particles of the liquid being of greater size than the intermolecular spaces of the solid.

It is easy to give proof of the fact that fluids do actually penetrate between the molecules of certain solids. When we wet a piece of paper it will fall to pieces of its own weight. Now it is impossible to attribute this to the mere passage of the liquid through the pores we observe with the microscope; for in that case the cohesive powers of the paper would not be diminished, any more than they are in a sponge. To destroy or diminish the power of cohesion the liquid must act between the molecules of the paper.

Another proof is, that if there be a rent in the membrane of the endosmometer, no endosmose or exosmose will ensue. There will be, simply, a rapid intermixture of the internal and external fluids.

Besides the intermolecular spaces penetrable by fluids, most organic solids have another species of porosity, which we may term *spongiosity*. Such is seen in the spaces between the cells of vegetables, their proper vessels, etc., also in the capillary vessels, veins, lymphatics, small arteries, excretory ducts, etc., that permeate animal membranes.

This being premised we now go on to the explanation of the phenomena of endosmose and exosmose.

When a liquid is poured into the endosmometer, and this subsequently plunged into another fluid, it is plain, that in immediate contact with a porous membrane we have two substances

to which in all probability it is related by different attractive forces. Let us at first, however, suppose the simplest case; that in which a concave meniscus is formed in each of the small capillary tubes of the membrane; or in other words, in which there is a rise of the fluid in the tubes. It is obvious that in such a case both of the fluids must enter the membrane and mingle there with each other. This fact is made evident when we employ two liquids that act chemically on each other, so as to produce a compound of different colour. If we use prussiate of potash on one side of the membrane, and sulphate of iron on the other, the membrane will be dyed blue. If we use acetate of lead and sulphuretted hydrogen, we shall have a precipitate of lead on the membrane. The two liquids, then, mix in the membrane. Suppose the attraction of the membrane for each of the fluids to be equal. The fluids will then permeate the membrane in equal quantities in equal times. The fluid in the endosmometer will reach the outerside of the membrane in the same quantity, and at the same time, that the exterior fluid reaches the inner side of the membrane. Now, as between any two bodies that attract each other, the attraction is reciprocal, the two fluids will be removed from the membrane in equal quantities in any given time. Hence in this case, there cannot be an accumulation of fluid on either side of the membrane;—the level in the endosmometer will remain the same throughout the experiment; yet if we use chemical tests, a transmission of both fluids can be demonstrated. It will be seen by a reference to the tables of Dr. Mitchell, that carbonic acid gas and nitrous oxide, when compared with common air, have nearly equal rates of penetration; so that we should infer that very little endosmose would occur, if we placed them on the opposite sides of an animal membrane, and experiment proves the inference to be correct. Again, olefiant gas and arsenuretted hydrogen have, according to Mitchell, exactly equal rates of penetration, and experiment testifies that no accumulation takes place on either side of the membrane when these gases are the subject of experiment.

It was inattention to this circumstance, that led Dutrochet to

term sulphuric acid and sulphuretted hydrogen, *inactive* solids, or enemies of endosmose and exosmose. He thought that they immediately and entirely arrested the transmission of liquids through the membrane. Such, however, Dr. Mitchell has proved not to be the case. Pure water and a solution of sulphuretted hydrogen, when separated by an animal membrane, produced indeed no endosmose, but the instant the endosmometer came in contact with the water a reciprocal and rapid transmission took place, as was proved by the chemical test, acetate of lead.

Now let us suppose the attraction of the exterior fluid for the membrane, to be greater than that of the interior, or in other words, that a concave meniscus is formed by the outer fluid in each of the small capillary tubes which permeate the membrane, whilst only a plane surface is formed in them by the inner fluid. Of course more of the exterior fluid will reach the inner side of the membrane in a given time, than of the interior fluid the outer side. Hence, (the attraction of the two fluids being reciprocal,) more will be taken up on the inner side than on the outer side, and endosmose will of necessity be the result; and this accumulation in the endosmometer, will necessarily go on until one of three things occur. 1. A change in the interior liquid, as when it becomes putrid. 2. An alteration of the membrane itself, as occurs when we use strong acids or other chemical re-agents. 3. An admixture of the two fluids, so that a homogeneous substance comes to exist on both sides of the membrane. In this latter case, any further alteration in the height of the column will be due to gravity, outward evaporation, or some other extraneous cause.

Of course, circumstances being reversed the same reasoning will explain exosmose, or the accumulation outward.

But we may go still farther, and suppose the interior fluid instead of a plain surface, forms a *convex* meniscus in the capillary spaces of the membrane. In such a case, the endosmose would be far more rapid, in consequence of the outward transmission being null. Probably this happens when we employ

nitrogen gas, the stronger syrups, and solutions of gum-arabic on one side, and water on the other.

The rate of the transmission of fluids through membranes, is then an affair between each fluid and the membrane, and depends upon the force of their reciprocal attraction. Dr. Mitchell ascertained by experiment, that gum-elastic and dry bladder became enlarged by the absorption of gases.* In other words, they absorb gases just as charcoal does; but being elastic and yielding to pressure the gas taken into their pores causes an enlargement in bulk. The existence of a fluid on the other side, capable of taking up the whole of the other fluid as soon as presented, is necessary of course to make *evident* the transmission at its maximum.

The force of endosmose will depend on the rate of transmission together with the existence in the endosmometer, of a fluid possessing less attraction for the membrane than the exterior fluid, but at the same time capable of taking up the latter as soon as presented. If the outer fluid form an extreme concave meniscus in the capillary spaces of the membrane, and the inner fluid an extreme convex meniscus; the force of the endosmose will be greatest. Hence sulphuretted hydrogen exteriorly, and nitrogen interiorly, should produce most striking effects,† and such is, in fact, the case. Ammonia in the place of the sulphuretted hydrogen would no doubt produce still greater effects.

* Op. cit.

† "Of all the gases," says Dr. Ure, "sulphuretted hydrogen is the most deleterious to animal life. A greenfinch plunged into air which contains only one fifteen hundredth of its volume, perishes instantly, a dog of middle size is destroyed in air that contains one eight hundredth, and a horse would fall a victim to an atmosphere containing one two hundred and fiftieth.

Dr. Chaussier proves, that to kill an animal it is sufficient to make the sulphuretted hydrogen act on the surface of its body, *when it is absorbed by the inhalents.*

It does not appear difficult to understand why so penetrating and poisonous a gas as sulphuretted hydrogen should often exist in the intestines without injury, for being mixed up with other gases, its tendency to infiltration is greatly restrained. When undiluted its diffusion through the whole system is fearfully rapid.—*Mitchell, Op. cit.*

We now see why in the experiments of Dutrochet, some porous solids, as carbonate of lime, free-stone, etc., produced neither endosmose nor exosmose; whilst others, as slate and baked clay, produced effects equal to those of animal membranes. For if convex menisci were formed on each side of the membrane no transmission could occur. We have already shown that the phenomena observed in capillary tubes, does not depend on the thickness of the tube, but rather on the substance composing it and the liquid which enters it; for tubes of the very same calibre produce very different effects with different liquids.

We see also, why alcohol placed in the endosmometer, produces endosmose with water if the intervening membrane be an animal one; but exosmose, if the membrane be of gum-elastic. That animal membranes have a stronger attraction for water, than they have for alcohol, is evident from the fact of their solubility in water, and insolubility in alcohol. It is well known, we preserve many anatomical preparations by immersing them in diluted alcohol: on the contrary, they quickly putrefy in water.* It is the reverse with gum-elastic. Ether and alcohol dissolve it; water, on the other hand, has an effect upon it scarcely perceptible.

There is another agent (elasticity) engaged in these phenomena which ought not to be overlooked.

Dr. Mitchell found by experiment that dry bladder and gum-elastic increased in bulk by the absorption of gases. Of course, to do so, some resistance must have been overcome: the capillary tubes (or spaces) of those porous substances must have been enlarged. Now these substances, we know, are eminently elastic, so that there is a force constantly acting on the gas absorbed, tending to expel it. The expulsion cannot, however, occur, so long as the attractive forces of the fluid and solid are superior to the elasticity;—but it will take place as soon as any other substance comes in the vicinity of the fluid, having an

* Dr. Stevens (On the Blood, p. 76,) asserts that if we put a mixture of alcohol and water into a bladder, and expose it to the atmosphere, the water is removed, leaving the alcohol; and that in this way we can obtain a pure spirit of a stronger proof than we can by distillation.

equal attraction for it, for then the elastic pressure of the retaining solid will evidently assist the attraction of the other substance for the fluid.

This agent is undoubtedly at work in many of the experiments related by Dutrochet. He himself was aware of it, and expressly asserts that in the phenomena of endosmose and exosmose, two forces were in operation—one of "adfluxion," and the other of "Impulsion." This force of adfluxion is what we have said ;—the reciprocal attraction of the solid substance and the fluid. The force of Impulsion is elasticity.

The agency of elasticity may perhaps be made clearer by another example. Suppose a solid piece of gum-elastic, of which one end only is exposed to a certain gas. The gas will be absorbed and that portion of the gum-elastic which absorbs it, will tend to enlarge itself. There will be then, in this portion of the gum-elastic a quantity of the gaseous substance influenced by two forces; attraction tending to keep it there, and elasticity tending to expel it. But as all parts of the gum-elastic have an equal attraction for the gas; it must follow, that the gas at length be diffused throughout the entire mass. Hence the gas would arrive at portions of the solid substance not directly exposed to it. These effects produced by elasticity it is important to attend to; for it is an agent deeply concerned in many phenomena, both of vegetable and animal life.

It now only remains for us to take notice of some experiments by Dutrochet and Mitchell, in which the fluid absorbed was transmitted into a vacuum.

Dutrochet having put an empty cæcum, secured with a ligature into water, found that a few grains of water had penetrated the membrane, and accumulated in the inside.

This is not difficult to explain. The water was forced inward by the outward pressure—just as occurs when it passes through an earthen porous vessel.

Dr. Mitchell attempted to produce a vacuum, first by the air pump, and afterwards by the Torricellian method. The gases penetrated the membrane and filled the empty space. But Dr. M. himself admits, that these vacua were only partial. We

cannot produce a complete vacuum by the air pump; and even in the Torricellian vacuum there is some vapour of mercury. He found, moreover, that "a perfectly empty bag carefully closed and placed in carbonic acid and nitrous oxide successively, did not undergo the slightest inflation. If a very small portion of *any kind* of air remained in the bag, inflation followed, provided the bag were exposed to a different gas."*

These experiments not being satisfactory, he performed another. "Closing," says he, "a tall cylindrical lamp-glass at one end with gum-elastic, and filling it with mercury, it was placed so filled on the shelf of the mercurial trough, having the end closed by the membrane uppermost. Through this fine film the mercury could be plainly seen in close contact with its under surface, while the deep depression of the membrane showed the power of the column of mercury by which it was drawn down. By leaving it in the air, or by placing over it a bell-glass of any gas, more slowly, but at their settled rates, the gases penetrated the membrane and accumulated in the cylinder, thus permitting the descent of the mercury. The process continued long after the mercury had abandoned the surface of the membrane, and the space was occupied by the gas, in of course, a rarefied state."†

Here again the effects are chiefly produced by pressure. For on the upper side of the membrane we have the weight of the atmosphere, or the tension of a gas equal to it; and on the under side, the same, minus, the weight of the column of mercury. The greatest pressure is then exerted on the upper side of the membrane, and the slow accumulation of the gas in the lamp-glass is caused thereby.

Since the above was written,‡ the 35th No. of the American Journal of the Medical Sciences has been issued, containing a paper by Dr. Draper on absorption. The views taken by this

* Op. cit. † Ibid., p. 38.

‡ The foregoing essay was written in 1835;—the application to physiology has been added since.

author nearly coincide with what is expressed above. He has further illustrated them by novel and beautiful experiments, and has established at the same time two points which it becomes me to call the reader's attention to.

1. He succeeded by a beautiful experiment, in interposing a thin film of a liquid between two gases—thus substituting a fluid, for the solid membranes used by Dutrochet and Mitchell. The effects were the same—the gases penetrated the liquid film and appeared on the opposite side.

2. He has pointed out in a clear manner, the mode in which a substance interposed between two gases may bring about a decomposition of them, provided the other is being constantly removed, or does not permeate the membrane likewise.—"Having," says he, "taken a tube, one end of which was expanded into a trumpet shape, and closed with a thin serous membrane—peritoneum stripped from the liver—which was tightly tied on by a wax thread; while it was wet, I poured through the orifice, which was open, a strong but *clear* solution of litmus in water. The tube thus situated, was placed in a wine-glass containing strong alcohol, and the level of the liquid inside and outside made to coincide. The conditions for decomposition were thus fulfilled, the water could find a ready passage through the serous membrane, but the colouring could not. Now, on arriving at the under side of the membrane, the water either was removed by uniting chemically with the alcohol, or by sinking mechanically through it to the bottom of the glass. Complete decomposition was effected, all the colouring matter being retained above the membrane, and, on placing a candle on one side of the glass, and the eye on the other, dense striæ of colourless water were seen passing through the alcohol, but not a particle of the litmus escaped."

Messrs. Lawrence and Coates* had already proved that pulverulent substances, such as cochineal, red saunders, arnatto, tur-

* An account of some further experiments to determine the absorbing power of the veins and lymphatics.

meric, and prussian blue, could not be detected in the blood after being thrown into the abdominal cavity.

These facts are interesting, as they give the answer to Majendie's objection concerning constant interstitial absorption;—which was, that the marks left on the arms, etc., of sailors who had undergone the operation of tattooing were permanent.

Dr. Draper calls our attention to the decomposition of the atmosphere by water. If water recently boiled be exposed to atmospheric air, it will take up more oxygen than nitrogen. Hence the air obtained from water by boiling, is isomeric with protoxide of nitrogen, i. e., 1 oxygen + 2 nitrogen; whereas atmospheric air, is 1 oxygen and 4 nitrogen.

Of the experiments proving the passage of gaseous substances through liquids, I select the following:

"A glass tube $\frac{1}{8}$ of an inch in bore, and seven or eight inches long, is to be drawn out at one extremity to a capillary termination, and when the bubble is to be blown, the other end is dipped into a solution of soap. The tube having been previously passed through a cork, is now to be introduced into a clean phial or bell-glass, whose neck the cork fits loosely; on blowing at the capillary termination the bubble slowly expands in the phial, where it is protected from access of air. To measure its diameter I take a strip of white pasteboard and divide it into inches and decimals, placing it in such a position before the phial, that it should cross the bubble diametrically; then with a small telescope that magnifies twelve or twenty times, and at the distance of about eight feet, I observe the bubble much magnified, the micrometrical pasteboard apparently passing through its very substance. Through a soap bubble 1·53 inch in diameter, whose substance, previous to expansion, was contained in a cylinder $\frac{1}{8}$ inch in diameter and $\frac{1}{4}$ in height, ammonia, either pure or diluted with atmospheric air, passes instantaneously, when air from the lungs is on the other side. Into the bottle in which the bubble is to be blown, a little strong solution of ammonia is to be poured, the bubble is then expanded; at a particular point it becomes dyed with the richest hues, and that

moment the phenomenon of endosmosis is complete. Care must be had to suffer no moisture from the mouth to close the capillary termination of the glass tube—and now a rod dipped in muriatic acid, is to be brought over the opening; as the bubble is collapsing by the attraction of its own parts, dense fumes of muriate of ammonia make their appearance, which continue until the substance of the bubble has entirely returned into the tube. The extraordinary rapidity of this action is remarkable. The bubble is scarcely blown, before it is full of ammonia; and it is not less interesting to observe how the colours play with change of atmosphere. A little cylinder expanded to the size of a pea, which, in common air, is opaque white, and which would not be coloured until expanded to six or eight times that diameter, becomes deeply tinged as soon as it is penetrated by ammonia. If restored to the free atmosphere it loses all its beauty, and these alterations may be kept up at pleasure by merely changing it from one medium to another."

Further on, the author remarks: "This experiment does not alone prove that endosmosis takes place through liquids and tissues whose pores have no sensible size, it has a much more interesting application. Physiologists know that the primitive form of all organic bodies is an imperforate vesicle or globule, having the power of absorbing those substances which are around it, and decomposing them. The ultimate vesicle yields to analysis the elements of water and a few salts. It is a centre of vital activity, a laboratory assimilating things for its own substance. The simplest plants, confervæ, tremellæ, and the simplest animals, consist alone of this structure. Let us observe how nearly this vesicle agrees both in its constitution and mode of action with the vesicle of the above experiment. Like that, it is not only an imperforate, but also consists of the very same elements. The properties which the organized vesicle is supposed to enjoy, are met with in the fullest extent in that which is not organized. Both have powers of endosmosis and a species of assimilation of things exterior to their own substance. What properties have the lowest order of animal and

vegetable life which that bubble does not possess? A thing thus endowed with vitality may well excite our interest—it breathes, it is nourished, it exhales."

Remark.—The author is in error in the last sentence. The bubble does unquestionably *absorb* and *exhale*, but it is not *nourished*. Neither assimilation nor secretion goes on within it: otherwise it were a living being.

PART II.

ABSORPTION.

Application to Physiology.

There are three ways in which foreign substances may enter the human system;—by the skin, by the alimentary canal, and by the lungs. In the first mode I, of course, include those instances in which substances are absorbed from wounds, blisters, etc.

It was once supposed that absorption was performed by a set of vessels, the lymphatics, which on this account were also called the absorbents. This opinion has been more than sufficiently refuted by a host of experiments. It has been proved beyond question, that absorbed substances are oftener or sooner found in the veins than in the thoracic duct.

It was then supposed that the veins were the sole organs of absorption; but the veins have no open mouths, and substances absorbed into the system have been frequently found in the lymphatics and thoracic duct.*

* "Four kittens were bled to what is commonly considered death. The blood ceased to flow from the divided carotid, and voluntary motion was extinct. Prussiate of potash in solution was then thrown into the abdomen. It appeared at the thoracic duct in five and a half, five, fourteen, and twelve minutes respec-

In fact, no vessels whatever are the organs of this function. Absorption takes place through the *tissues*,—the fluids passing through them intermolecularly. The vessels are the recipients, the mere channels of conduction by which the absorbed substance is thrown upon distant parts. That such is really the case, we know from the following facts.

1st. Absorption takes place in tissues (the serous, for instance) in which no vessels with open mouths can be detected by the most powerful microscopes.

2. It is a function performed with great energy by whole classes of plants and animals that have no vessels whatever.

3. It is performed by dead membranes, as well as by living ones.

4. It is performed during germination, by the seeds of plants; and during incubation, by the ova of animals before the possible existence of any vessels.

5. It is performed by lymph effused on the surfaces of membranes, or into the interstices of the tissues. The formation of vessels in effused lymph is always preceded by absorption.

6. To suppose this function performed by vessels, we must pre-suppose the vessels to have open mouths like the lachrymal duct or the suckers of several of the entozoa. But we shall look in vain for such vessels on any of the membranes, even with the assistance of the most powerful microscopes. Nay, it has been shown by Magendie, that liquids are absorbed directly through the coats of the larger veins and arteries. The following is his own account of the experiments:—

"I took a young dog about six weeks old. At this age the walls of the vessels are thin, and, therefore, fitter for the success of the experiment. I exposed one of the jugular veins, and isolated it perfectly throughout its whole extent. I carefully removed all that covered it, especially the cellular tissue and some

tively. In the last two, the great vessels originating at the heart were secured by a common ligature. The blue colour was in every instance perfectly distinct." *An account of some farther experiments to determine the absorbing power of the veins and lymphatics, by J. O. B. Lawrence, M.D., and B. H. Coates, M.D.*

small vessels that ramified in it. I then placed the vein upon a card in order that it might have no point of contact with the surrounding parts. I then let fall upon the vein and about the middle of the card, a thick and aqueous solution of the alcoholic extract of nux vomica, a substance whose action is very energetic upon dogs; and took care that no portion of the poison should touch any thing else than the vein and the card, and that the courses of the blood should be free in the vessel. Before the fourth minute the effects I expected were developed, feebly at first, but afterwards with so much activity that I was obliged to resort to insufflation of the lungs, to prevent the death of the animal."*

He afterwards tried the experiment upon the carotid artery, with the same result. To assure himself that the poison had really traversed the coats of the artery, and had not been absorbed by small veins which might have escaped his attention, he split the artery, when the bitter taste of the nux vomica was recognised upon its internal coat by himself, and all the by-standers.

In addition to all this we should be obliged to suppose these absorbent vessels distributed throughout every part, even the most minute, of the economy, since liquefaction and removal of the old solids are continually going on. The vessels themselves undergo this process: can it be imagined that they absorb themselves?†

How absorption occurs in dead substances I have already shown; but living beings exist under peculiar circumstances which so modify the phenomena that at first view they seem inexplicable by the same laws.

It must be borne in mind that in all living beings whatever,

* Précis. Elémentaire.

† "When his (John Hunter's) opinions on the functions of the absorbents were first promulgated, they appeared to others, not merely wild, but absolutely incredible; and when he was asked, how he could suppose it possible for these vessels to do such things as he attributed to them; he answered, nay, I know not, unless they possess powers similar to those which a caterpillar exerts, when feeding on a leaf."—*Abernethy's Physiol. Lect.*—Lect. v.

a peculiar chemical process is incessantly going on;—in fact, that it is this process (the assimilation of the nutritive fluid) which constitutes them living beings, and that when it ceases, death occurs.

The influence of nutritive action over absorption is very well shown in the ascension of sap in plants, and in the phenomena of erection and inflammation in animals—processes which have been described and explained elsewhere.*

The influence consists in this;—that in proportion to the intensity of the nutritive process will be the removal or ejection from the tissues of the absorbed substance, provided it does not combine with them; and in proportion to the rapidity of its removal, will be the flow of the absorbed substance into the tissues.

Another circumstance which modifies absorption in living beings, is, the existence of vessels, and in the higher animals, the existence of a heart and of a complete circulation of the blood.

Substances absorbed into the system first pass into what are termed the capillary vessels, of which, correct notions must be formed. These vessels differ from the veins and arteries, not only in their extreme tenuity, but also in the frequent anastomoses which they form with each other; but in no other particulars. Those processes, heretofore attributed to some mysterious agency on the part of the capillary vessels, such as interstitial deposition and absorption, are phenomena with which the capillary vessels (except so far as they too are parts of the living system) have nothing to do. The capillary vessels are the mere termination of the arteries and beginning of the veins,—channels of conduction simply, and possess no properties which belong not to the other vessels.

Do the capillaries possess membranous tunics, or are they mere spaces in the tissues, similar to the channels we observe in a sponge? The reader will find this question discussed in Müller, who advances the following reasons for believing the serous coat to be continuous from the arteries to the veins.

* See chapters 6th and 8th.

Fluids injected into the arteries pass frequently into the veins without extravasation.

Currents cross above and below each other without uniting or interfering with each other.

"The number of the currents," says Professor Müller, "and indeed the smallness of the islets of solid matter between them in the pulmonary membrane of the frog and salamander also tend to prove that membranous tubes must exist, for these small islets would otherwise be themselves sometimes involved in the currents. But there are also direct means of proving the existence of the membranous tubes around the capillary streams. For this purpose we must select a very delicate parenchyma, which easily softens and dissolves in water, so as to leave behind the net-work of capillaries. In a piece of the cortical substance of the kidney of a squirrel which had been laid in water for a short time only, but long enough to have become softened, the capillary vessels which are interlaced around the tubuli uriniferi appeared to me, when I examined them by the microscope, to be independent parts. In the choroid, iris, and ciliary processes the capillaries are still more evidently substantial independent parts."

Besides the capillary vessels which carry red blood, there are also the capillary vessels of the lymphatic systems. They spread in a net-work through the tissues, have no *direct* communication with the arteries, and carry lymph, a liquid which seems to be identical with the liquor sanguinis.

We can now easily understand how substances are absorbed from the surface of the body. When a fluid—for solids cannot be absorbed—comes in contact with the skin, it is separated from the living tissues by the epidermis,—a sort of varnish protecting the true skin. If time be allowed, the epidermis will unquestionably take up the fluid; the true skin will take it from the epidermis; it will pass through the thin coats of the capillaries; be taken up by the blood, and be thus swept into the torrent of the circulation. Of course, when the epidermis is removed, as in blisters, wounds, etc., the absorption takes place much more rapidly.

As has been already mentioned, the existence of a current continually flowing through the capillaries into the veins, must greatly promote the rapidity of the absorption. Hence absorption must always be more rapid in living membranes than in dead ones.

As besides the capillary system carrying red blood, there also exists that of the lymphatic system: it is obvious that some portion of the absorbed substance may find its way into the circulation by way of the lymphatics. But as the current in the veins is far more rapid than in the lymphatics, much the larger portion must be carried by the veins.

It is clear too that absorption will be more rapid, the better the absorbing tissue is supplied with vessels, and is unprotected by other substances. Thus absorption takes place from the pleura more rapidly than from the peritoneum; more rapidly from the peritoneum, than from the mucous tissues, which are protected by their proper secretion; and more rapidly from the mucous tissue than from the skin. "We can prove," says Majendie, "by experiments, most of the truths which analogy alone should make us admit; and you will see in a way the most manifest, that the mucus of the intestines, though retarding, does not offer so complete an obstacle to imbibition as the epidermis. I plunge the paw of this rabbit into an alcoholic solution of nux vomica, a substance, the activity of which you are acquainted with. Already some seconds have passed and yet no symptoms of poisoning are manifest. In fact, it is with the paw of the animal as with the hand of the operator; the presence of the epidermis opposes the imbibition of the poison into the vascular net-work of the skin. I now inject by the rectum into the large intestine of the animal a quarter of a *gros** of the same alcoholic solution. Observe what passes. The mucous surface, at this point, receives fewer blood-vessels than the stomach or small intestines, and this anatomical arrangement will explain to you the slowness of the absorption of the deleterious substance. Already the animal appears unquiet, he

* About 16 drops.

seems to be occupied with some internal sensation, his limbs are stiffened,—he is dead. Compare now the results which we have just obtained, with the rapidity of imbibition that takes place on a serous membrane, such as the pleura."*

Absorption will also be more or less rapid, according to the constitution of the tissues. "We must now see whether the different tissues of the body are alike with regard to imbibition. Here is the paw of a rabbit which I have separated from the body, and which I have macerated for some time in ink. Dissecting the limb with care, we find that the skin shows fewer traces of imbibition than the cellular tissue in which the colouring matter appears much deeper. The veins and arteries are also less penetrated by the solution. You see, also, that through this serous membrane, which is stretched out, the liquid is imbibed with the greatest facility."†

Again, different fluids are not absorbed with equal rapidity. Alcohol is absorbed more rapidly than water; ether, than alcohol. "If I take a piece of chamois leather and plunge one of its extremities into coloured water, and the other into an alcoholic solution, what takes place? You see that the alcohol is absorbed much more quickly than the water. It is thus that if you take into the stomach a glass of brandy, for instance, you experience almost immediately the generous effects of the liquor, whilst a glass of simple water will be a long time without manifesting its action. If I substitute ether for the alcohol, the imbibition will be still more rapid."‡

The same fluid is absorbed more rapidly the higher its temperature, provided it be not so high as to affect the constitution of the tissues. This is owing to an obvious cause—the diminution of density in the fluid.

Different sides of the same membrane may possess unequal absorbing powers. "If you fill a piece of skin, disposed in form

* Leçons sur les Phénomènas Physiques de la Vie., tom. i. p. 43.

† Majendie, op. cit. tom. i. p. 30.

‡ Majendie, op. cit. tom. i. p. 29. This is not in accordance with the experiments of Dutrochet, who asserts that water is absorbed more rapidly than ether or alcohol, if the intervening membrane be an animal one.

of a bladder, with water, the epidermis being outward, you will see the liquid separate, by degrees, the epidermis from the chorion; accumulate in the space between; and thus mechanically produce a true phlyctema, which will last many days. If, on the contrary, you reverse the sack, so that the water be in contact with the epidermis, the evaporation is very rapid. Thus the two surfaces of the epidermis are far from possessing an equal permeability. This phenomenon is very curious, and is owing doubtless to some unknown anatomical arrangement, a special study of which would be important."*

Electricity has also an influence upon absorption in the living system, as it has upon capillary attraction and the phenomena of endosmose and exosmose. "One of my old pupils, Professor Fodéra, has made some very curious experiments on this subject. He found that if a solution of prussiate of potash be put upon the mucous coat of the intestines of a dog, and a solution of sulphate of iron on the corresponding serous surface, the imbibition is at first very slow; but if a galvanic current be passed through the coats of the intestine, the imbibition is much more rapid, and the surfaces are soon turned blue."†

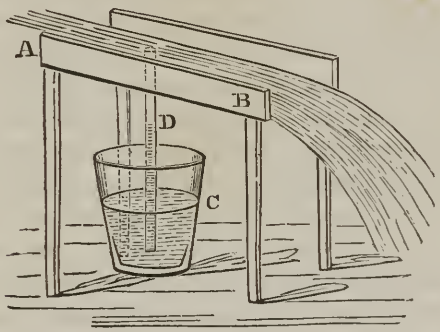
If fluids are thus absorbed by the tissues and taken into the circulation, it may be thought that substances in contact with the body should also absorb from the tissues. There is no question that this does occur to a certain extent. Thus, the atmosphere takes up matters exhaled from the lungs and skin. Warm baths may act in the same way. Poultices also, particularly when applied to inflamed parts, in which the circulation has become retarded, may, in fact, exert their influence by abstracting from the blood, as well as by yielding to it. But there is one circumstance which in living beings will always determine a flux inwardly in greater quantity than outwardly. That is, the existence of a current passing through the capillaries into the veins. For a current, flowing in a given direction, will draw to it all fluids that are quiescent, and within the range of its attraction.

* Majendie, op. cit., tom. i. p. 99.

† Ibid., tom. i. p. 129.

When two fluids lie at rest near together, they attract each other, and they may or may not coalesce according as the

FIG. 4.



force of their reciprocal attraction is great enough or not to break up their inertia. But when one is in motion and the other quiescent, the momentum is added to the force of attraction, and the fluid at rest is drawn to the one in motion. This law may be exemplified by a simple experiment. Let A B represent an inclined trough, over which a current of water is passing. C is a glass tumbler half-filled with water; D a small tube open at both ends, passing through the bottom of the trough and reaching near the bottom of the glass. Instead of water falling through the tube into the glass it will be carried up the tube.

Internal pressure has a great influence upon absorption. This is proved by the following experiment of Majendie. He injected water into the veins of an animal in such quantities that considerable tension of both veins and arteries was produced. He now found that poison, such as the alcoholic extract of nux vomica and others, produced no effects whatever when injected into the tissues. In fact, absorption did not take place; as soon, however, as the tension was relieved by the lancet, the usual effects of the poison were manifested.*

* Précis. Elémentaire.

Absorption and exudation of the same substance cannot go on at the same time through the same tissue. This must be obvious at first sight. Hence poisons secreted by the organs of the viper, rattlesnake, etc., remain in contact with the tissues that secrete them, without injurious effect; but if applied to other parts, they act as they would upon other animals. In cases where pus or other substances have been absorbed back into the system, a change must have occurred either in the constitution of the tissues themselves, and, therefore, in their actions, or in the fluids secreted. In this way a secernent tissue may become an absorbent one;—a circumstance which frequently occurs from the influence of the nervous system.

We see here a reason why the gastric juice does not act upon the mucous coat of the stomach during the digestive process: for to dissolve the stomach it must first be absorbed, which cannot happen,—the stomach itself undergoing these organic actions by which the gastric juice is eliminated. When life ceases, this fluid reacts on the stomach and digests it in common with the other organic substances it may contain.

The principles inculcated above, are spoken of principally in reference to absorption from the skin; but they apply also to absorption of foreign matters from the lungs and alimentary canal, with these exceptions; that the lungs absorb much more rapidly than any of the other organs, and that certain substances, such as some of the animal poisons, are rendered harmless by digestion in the stomach. Of the absorption of chyle by the intestine and of oxygen by the lungs, I shall speak presently.

Exhalation.—The exhalations are fluids which transude through the tissues without rupture of the blood-vessels, and which are found already formed in the blood, making a portion of that fluid. They must, therefore, be distinguished from the secretions—for a secretion is not found in the blood, but is the product of the chemical actions which occur between that fluid and the solids. Semen, bile, milk, etc., for instance, are secretions not exhalations: they are not found in the blood, though they are formed from its materials.

Exhalations may occur from closed or unclosed membranes.

In the first case, if the exhalation be in excess, we term it a dropsy ; in the latter, a flux.

From all parts of a living body exposed to the atmosphere, an exhalation is continually going on. This is a mere physical phenomenon,—cæteris paribus, precisely the same with evaporation and subject to the same laws.

The interior actions going on in the economy, however, exercise a great control over the fluids furnished from the blood; and modify to a considerable extent their evaporation. Thus, exhalations are increased in sleep, and diminished in fever.

In truth many circumstances modify the exhalations both in quantity and kind. I shall enumerate some of the most prominent.

Pressure.—If a large vein be tied, or if a tumour press upon it, an obstacle is made to the passage of the blood to the heart. That organ, however, continues its action, and the arteries conduct the blood into the tissues. Hence congestion in the tissues, enlargement of the veins, and finally extravasation of the more fluid portions of the blood into the cellular tissue. Induration of the liver may thus produce ascites; that of the lungs, hydrothorax. Enlargement with dilatation of the right ventricle of the heart, will cause an imperfect play of the tricuspid valves,—the blood will be driven back from the ventricle on the auricle, and thence upon the vena cava. The blood, therefore, is prevented from passing, as it should do, through the heart; and thus are produced those *general* dropsies attendant upon such diseases.

Sub-irritation.—Fluxes from the serous and mucous tissues frequently occur from a slight irritation caused by cold or some other cause. The fluids are drawn in larger quantities into the tissues and transude from them by the *vis à tergo* action of the heart. When the irritation runs higher, the exhalation may altogether cease. In this case, nutritive action being greatly increased, the affinity of the blood and solids are also increased, and the fluids are retained by the attractive force of the solids.

Increase in the rapidity of the circulation.—After much ex-

ercise such as running, leaping, etc., the exhalations are greatly increased.

Nervous affections.—This has been treated of in the chapter on adynamia.

The sudden increase of the quantity of the circulating fluids.—We have seen that by filling the blood-vessels with blood or warm water until considerable tension was produced, we prevented, or at least greatly impaired, the process of absorption. The same condition will of course promote exhalation. From this cause—tension of the blood-vessels—it happens that we sometimes have fluxes or dropsies in other parts, from the sudden disappearance of an ascites, etc.,—a sudden suppression of some of the secretions may also produce the same effect.

Changes produced in the blood or in the tissues.—Exhalations frequently occur from this cause at the close of miasmatic and other diseases. The normal relations of the nutritive fluid and the tissues are broken up—the blood arises at the spot and passes through either entirely or in part, from the *vis à tergo* action of the heart. The black vomit of yellow fever is caused in this way;—the colouring matter having been turned black by the acid contents of the stomach.

These exhalations may be merely the serous portion of the blood containing fewer or a greater number of salts, and more or less albumen. In other cases they may contain, or principally consist of, the fibrinous portion of the blood—sometimes they contain a portion of the colouring matter. Frequently we find them mingled with peculiar secretions.

It will be observed, however, that whatever be the remote, the *immediate* causes of these exhalations are chiefly the action of the heart and the tension of the blood-vessels.

Re-absorption of the exhalations.—It was mentioned above that absorption and exhalation of a substance could not take place through the same membrane at the same time. The supposition that it were possible, involves a physical contradiction. Before exhalations, therefore, can be absorbed from the cavities of the body, a change must take place either in the fluids exhaled, or in the exhaling tissues, or in both. Certain remedies,

such as quinine, iodine, mercury, digitalis, etc., operate in relieving dropsies by changing the condition and actions of the exhaling tissues; by converting them, in short, from exhaling into absorbing tissues. Others again act upon the skin, bowels and kidneys. By producing a flux from those organs, they change the constitution of the blood;—the exhalation ceases and the exhaled liquid is re-absorbed to supply the loss of the thinner portions of the blood.

A reply may be made here to an objection offered by Professor Müller. "Endosmosis," says he, "does not explain the absorption of all fluids by the animal tissues. If the fluids of the tissue itself are more concentrated than those to be absorbed, such as fluids collected in the pleura, or lungs, the passage of the external fluids into the parenchyma will, according to the laws of endosmosis, take place more readily than the passage of the fluids of the tissue outwards. But if, on the contrary, the external fluid is equally concentrated with that contained in the tissue, the two fluids ought, according to the laws of imbibition, to pass through the membrane in both directions with equal rapidity, so that the quantity of both fluids would remain the same; and, if the fluid of the tissue is the less concentrated of the two, it will exude in greater quantity than the external will be absorbed, as that the quantity of the latter will be increased. Imbibition, therefore, does not explain the diminution of the quantity of fluids by absorption, but only the mingling of them, as in the case of poisons applied to the surface of the body, etc."*

It is also known that liquids injected into the cavity of the pleura are rapidly absorbed. Now, where the exhalation has ceased, in what respect does the exhaled fluid differ from one injected artificially into the cavity of the pleura? Certainly in none whatever.

It is obvious that the Professor has neglected to take into account the continual *current* passing through the lungs. Were the blood stagnant in the lungs, the result would be as he sup-

* Physiology—trans. by Baly, vol. i. p. 248.

poses. But such is not the fact; the blood is being perpetually changed; the portion of the exhaled liquid taken up at any particular time does not remain in the tissues,—it is swept onward to distant parts of the system. Moreover, the blood is continually throwing off portions of its substance in the form of secretions, by the skin, liver, kidneys, etc.,—in short, it is being continually renewed.

Secretion.—After a secretion is formed by the chemical reaction of the blood with the tissues, it is thrown outwardly like the exhalations themselves. It is now known that all secretions, even those of the glands, are formed on the surfaces of membranes. The follicles and glands of the mucous tissue are but convolutions or corrugations of the membrane, and secretion takes place within them precisely as it does upon the plane surface of the membrane. In glands, such as the liver, kidneys, etc., the secernent organs are the ramifications of the excretory ducts, divided and sub-divided to a wonderful extent, and packed closely together. Upon these ducts the capillaries spread themselves in net-works of more or less complexity; the secreted matter is poured from the free surface of the tubes into the cavity, whence it finds its way outwardly by the common duct.

Professor Müller propounds the following questions: "Why does not the mucus collect as readily between the coats of the intestine as exude from the inner surface? Why does not the bile permeate the walls of the biliary ducts, and escape on the surface of the liver as readily as it forces its way outwards in the course of the ducts? Why does the semen collect on the inner surface only of the tubuli seminiferi, and not on their exterior—in their intestines? The elimination of the secreted fluid on one side only of the secreting membrane, namely, on the interior of the canals, is one of the greatest enigmas in physiology."*

He then goes on to give two hypothetical explanations; one of which is "that the capillaries of the gland are provided with

* Physiology, vol. i. p. 464.

exhalent pores so constructed as to allow fluids to pass through in one direction only, namely, towards the cavity of the glandular canals." The other explanation is "that the external surface of the glandular canals exerts a chemical attraction on the elements of the fluid, infusing into them at the same time a tendency to unite into new combinations, and then repels them, in a manner which is certainly quite inexplicable, towards the inner surface of the secreting membrane or glandular canals."

I am not satisfied with either of these explanations. The first, indeed, is rejected by Müller himself; and the other is incomprehensible. I am disposed to attribute the appearance of the secreted matter on the free surface of the membrane to the same cause that produces exhalation—namely, pressure exerted by the heart and blood-vessels. We must distinguish between the formation of a secretion and its appearance outwardly. The first is the result of a chemical action between the blood and the solids; the second is a mere exhalation of a liquid formed. Now the free surfaces of membranes are the points of least resistance—the pressure being à tergo. Hence, the fluid after being formed will make its appearance outwardly.

This explanation is rendered the more probable from the fact, that if we equalize the pressure in the reverse direction, (as we may do by tying the efferent ducts so that the tubes become filled with the secretion,) secreted matter is again absorbed. This occurs when calculi or inflammations cause obstructions in the biliary ducts: jaundice follows as a consequence.

We have, in truth, no secretion except from free surfaces. Even in abscesses, deposition of tubercles, etc., the secretions take place from the free surfaces of the cellular tissue and accumulate in its meshes. But we know that the solids, as muscle, brain, tendons, etc., wherefrom no secretion takes place, are being continually resolved into fluids, and as constantly renewed. These fluids are doubtless returned into the circulation by the veins; and the question now comes up, why it is that in one instance, the fluid is exhaled, and in the other, returned into the circulation? *Probably*, because in the latter case the pres-

sure exerted by surrounding parts, is more than sufficient to counterbalance the vis à tergo.

Is the fluid secreted derived entirely from the blood; or does it not contain also that portion of the solids resolved into fluids? In the present state of our knowledge this question cannot be answered.

Action of Poisons.—When soluble substances are taken into the stomach or lungs, or are applied to the abraded surface of the body, they must permeate intermolecularly the tissues to enter the capillary vessels; and in their passage, they will, according to their nature, affect the constitution of the tissues. Poisons, then, may produce a local effect; and this effect, by means of the nervous system, may be sufficient in some instances to cause death. Corrosive sublimate, arsenic, the mineral acids, etc., act upon the tissues with which they come in contact, and destroy them by chemical action. In these cases, death occurs as in cases of destruction of the tissues by heat or mechanical violence;—the patient may sink at once without reaction, or may perish from the effects of inflammation.

The narcotic poisons also produce local effects. Thus, the infusion of tobacco instantly paralyzes the heart when applied to it. A drop of the tincture of belladonna applied to the conjunctiva, will cause the iris of the eye experimented on to expand, whilst that of the other eye remains in its natural state. If we lay bare the sciatic nerve of a frog, isolate it from the other parts, and then apply to it a little laudanum, we shall destroy the function of that part of the nerve, but of that part only. For if we galvanize the nerve *below* the point to which the poison was applied, we will produce contractions in the muscles of the legs; whereas, if we galvanize it *above*, no effect is produced.

The rapidity of the action of some poisons, such as hydrocyanic acid and strychnine, have induced some physiologists to suppose that they affected the system by nervous radiation rather than by being taken into the circulation. The following experiments will prove this view to be erroneous.

1. If we isolate the sciatic nerve of a frog and pass a ligature round the thigh, so as to include all parts except the nerve, and then steep the leg in hydrocyanic acid or inject strychnine under the skin, no symptoms of poisoning will be produced.

2. But if we divide all parts except the vein and artery, and then apply poison to the foot, the effects of the poison are manifested as usual. Magendie and Delille, in order to show that it was really the blood that carried the poison into the system, divided both artery and vein, and then connected their divided ends by means of tubes introduced into the vessels and tied firmly upon them. When the circulation was permitted to go on the effects of poison were produced in the usual time.*

3. If a ligature be thrown round the large vessels entering and issuing from the heart of a frog, none of the usual effects of poisons are produced.

4. If hydrocyanic acid or strychnine be inserted into the spinal marrow itself, no general symptoms of poisoning follow.

5. If we destroy a portion of the spinal marrow, and then poison the animal, convulsions will occur in all the muscles of the body except in those supplied by nerves from that portion of the spinal marrow which has been removed.

6. If an animal be poisoned with strychnine, general convulsions follow, but if we divide the sciatic nerve, the convulsions immediately cease in the leg operated on.

These and other experiments which might be referred to, prove beyond a doubt, that it is by absorption into the circulation that the general effects of poisons are produced; and not by affections of the extremities of the nerves radiated to the spinal marrow.

An objection may be made that when we thus cut off the circulation, as in some of the experiments related above, the nerve is no longer capable of transmitting the change it undergoes from the operation of the poison;—that the presence of arterial blood, in short, is essential, and that when it is cut off the substance of the nerve undergoes a change by which it becomes

* Précis. Elément.

unfit to propagate the effects of the poison. This hypothesis is refuted by the fact that the nerves (of cold blooded animals at least) do not, under such circumstances lose their irritability. A frog experiences sensations and leaps about for some time after the heart is cut out.

To suppose that poisons produce their constitutional effects by nervous radiation, would be to admit that chemical changes (not isomeric) in the constitution of the nervous matter, were propagated to the nervous centres. Of this we have no proof whatever, except in cases such as tetanus, tabes dorsalis, etc., in which it proceeds by a slow and gradual morbid process. When the nerves are destroyed by corrosives, heat, or any other chemical agent, an isomeric change accompanies the destruction; but the change in composition,—that change, by which the nervous matter has either gained or lost some substance, or has been transformed into fixed compounds, is not transmitted. To suppose it were, would be to admit that the whole nervous system was destroyed even in common cases of burns.

The narcotic poisons, therefore, produce their effects by first being absorbed into the circulation, and then being thrown upon the tissues, where they interfere with the process of nutrition. This interference occurs in all the tissues to which the poison may be distributed,* but the general effects and the speedy death result from their influence on the brain and spinal cord. That it is really by interference with the nutritive process that they cause their effects, is proved by the fact that when applied directly to the nerves or spinal cord itself, they produce no such phenomena. It is not, therefore, the prussic acid or the strych-

* Müller having cut away the vessels and muscles from the thigh of a frog, left the leg attached to the body by the nerve only. He then poisoned the frog, and found that the irritability of the sound leg was lost much sooner than that of the injured leg. "The leg, therefore," says he, "which received no blood was sensible to the influence of the spinal cord much longer than the other limb; the nerves and muscles of which had been exposed to the action of the poison circulating in the blood; so that it is going too far to maintain that the poisons act on the central parts of the nervous system only, they act, likewise, on the nerves through the medium of the circulation."—*Physiology*, vol. i. p. 629.

nine which produces the symptoms, but the *poisoned blood* which finds its way to the nervous centres.

It is indeed wonderful in how brief a time some of these poisons act,—in so short a time, indeed, that were it not for the most conclusive experiments, we could scarcely believe they were transmitted through the blood-vessels. In Emmert's experiments, the action of angustura, of the upas and of prussic acid, took place in some instances in from two to five seconds.* But our surprise will be somewhat diminished when we learn the extreme rapidity with which the circulation is performed. "With respect to the time in which the circulation of a single portion of blood is completed, the following results have been deduced by Hering from eighteen experiments on horses. The time required for the passage of a solution of ferrocyanate of potash of different strengths, which is mixed with the blood, from one jugular vein (through the right side of the heart, the pulmonary circulation, the left cavities of the heart, and the general circulation) to the jugular vein of the opposite side, varies from twenty to twenty-five or thirty seconds; from the jugular vein to the great saphæna it is only twenty seconds, from the jugular vein to the masseteric between fifteen and thirty seconds, to the facial artery in one experiment between ten and fifteen seconds, in another experiment between twenty and twenty-five seconds; in its passage from the jugular vein to the metatarsal artery it occupied between twenty and thirty seconds, and in one instance more than forty seconds. The result was nearly the same whatever was the rate of the heart's action."†

It would appear from the experiments of Magendie that the poisoned blood of one animal may be transferred to another without injury. I transcribe two of his experiments—"We separated the thigh of an animal from its body, in such a manner that it remained attached by only the artery and crural veins; we introduced the poison into the paw and transfused

* Müller's Physiology, vol. i. p. 628.
† Müller, Op. cit. vol. i. p. 186.

the blood of the crural vein into the jugular vein of a healthy animal. The flow of blood from one animal to the other, lasted more than ten minutes—a time more than sufficient to produce the effects of the upas. Nevertheless no sign of the action of the poison was perceived in either animal. One preserved perfect health; the other died in a few days in consequence of the amputation of the thigh and loss of blood.

"One must not think that in this experiment, the transfused blood possessed no deleterious qualities; for the following experiment will prove the contrary.

"As in the preceding experiment, I separated the thigh from the body. Three minutes after having introduced the poison into the paw, I transferred the blood of the crural vein into the jugular vein of another animal. The transfusion was continued five minutes without producing any effect; I then put a stop to it, and disposed things so that the blood of the crural vein might return to the body of the animal to which it belonged. Almost immediately, the animal gave evident symptoms of the action of strychnine on the spinal marrow."*

Messrs. Addison and Morgan performed a similar experiment with the like result; and they inferred from it that poisons do not act by being transferred along with the blood to the brain and spinal marrow, but that they act upon those organs by transmissions from the extremities of the nerves. The experiment of Magendie and Delille, already mentioned, proves, say they, merely this: that the poison entered the blood-vessels and mingled with the blood, but it proves nothing more. As soon as the poison entered the body, it acted on the coats of the veins, and the effect was transmitted by the nerves to the spinal cord.†

The inference drawn is plainly a forced one; for if, in the experiments of Magendie just related, the poison reached the animal into which the transfusion was made, it should have caused death; whether it acted on the nervous extremities or

* Journal de Physiologie, tom. i. p. 31.

† See Christison on Poisons, p. 11.

was transmitted along with the blood to the spinal cord and brain.

But there is no doubt, inexplicable as the fact may be, that the poison never reached the animal into which transfusion was made. This is clearly shown by the experiments of Vernière. He placed a ligature round the thigh of an animal so as to interrupt the nervous current but not the arterial. He then poisoned the animal by introducing the venomous agent into the paw. After waiting a while, he opened a vein below the ligature and injected the blood received into the veins of another animal. Death ensued as in usual cases of poisoning.*

It can scarcely be necessary to say that one experiment with positive results, is sufficient to set aside a thousand with results merely negative.

Absorption of Chyle.—The absorption of chyle has been supposed to differ from absorption in other parts of the body, and to depend upon laws peculiar to itself. Professor Müller thus states his objections to considering it a simple act of endosmosis. "If the lacteals in the intestine and mesentery be supposed to be filled with animal fluids, and chyme to be in contact with the villi or net-work of lacteals, the fluid parts of the chyme would, according to the laws of endosmosis, enter the lacteals; and the fluid, or dissolved parts of the matter already in the lacteals, would pass out and mix with the chyme; if the chyme were more fluid than the chyle in the lacteals—if the matters it held in solution were in a less concentrated state, the chyle would permeate the coats of the lacteals in an outward direction in larger quantity than the chyme would enter them. This, however, does not account for the wonderful process of absorption."†

Now if we regard the lacteals as an independent set of vessels, the sole function of which, is, to take up the chyle from the intestines and convey it, first to the thoracic duct, and

* Journal de Progrès. for 1827, tom. iii—or, Christison, p. 10.
† Op. cit. p. 282.

thence into the subclavian vein, the absorption of chyle would indeed be a mystery, and the objections of Professor Müller unanswerable. The facts would, upon the principles heretofore laid down, unquestionably occur as he has stated the case. But we cannot so regard these vessels, and from this point we see clearly enough into his error.

What are the lacteals? They compose a branch of the lymphatic system. They are the lymphatics of the intestines and the adjacent tissues, like to the other lymphatics in every respect, and differing from them in no particulars whatever. They are the same in structure, in possessing numerous valves, in passing through their proper glands, and in their termination —the thoracic duct. Moreover, we know from observation that the lacteals when the intestines are empty, instead of carrying chyle, carry lymph like the rest of the system. They are, therefore, the same in function.

The lymphatics,—what are they? They were once supposed to be the sole organs of absorption;—an hypothesis, which at the present day does not require a refutation. They compose a system of vessels which take their origin in the substance of the cellular tissue, or in those tissues which are modifications of the cellular, that is, the serous, mucous, fibrous, etc. According to Müller, they arise in two forms; first, by a very close net-work; and secondly, by small cells more or less regular, and communicating one with another. Uniting branch after branch, in the manner of the veins, they enter their glands, (the functions of which are unknown,) and finally end in one large trunk, the thoracic duct, which pours its contents into the left subclavian vein at its junction with the jugular. The fluid which these vessels carry, is termed *lymph*, a transparent, pale, yellow fluid; void of smell, slightly alkaline, and of a saline taste. Its composition is as follows, taking Lassaigne's analysis of the lymph of the horse:*

* Müller's Physiology, vol. i. p. 258.

Water, - - - - - - - - -	92.500
Fibrine, - - - - - - - - -	0.330
Albumen, - - - - - - - - -	5.736
Chlorides of sodium and potassium, with soda and phosphate of lime, - - - - - - -	1.434
	100.000

The lymphatic vessels at their origin have no direct communication with the arterial system as the veins have; but that the fluid they contain is simply a portion of the blood, is obvious from the constitution of the lymph itself. The liquor sanguinis deprived of globules and colouring matter has transuded intermolecularly through the tissues into the lymphatic capillaries, and thence finds its way back to the heart along the lymphatics, instead of by the veins. These vessels, in short, are simply the veins of the white tissues; and the causes which propel the blood along the veins to the heart, propel also the lymph.

Along the lymphatics, therefore, there is a current flowing towards the heart; a feeble current to be sure when contrasted with that in the veins; but still a current, a retrogade movement in which is impossible as it is prevented by numerous valves.* The moving powers of this current are chiefly the heart and the influence exerted by the nutritive process. But, as in the case of the veins, there exists the auxiliary power of the muscles, which, pressing upon the lymphatics, assist in propelling the lymph onward. In the lacteals, the vermicular action of the intestines no doubt aids in a great measure the process of the chyle to the thoracic duct.

Now, the existence of this current shows at once the source of Müller's error. In short, chyle is but the albuminous portion of the chyme, held in solution with water and some salts; and the chyme itself must be regarded as an external substance in

* And be it remembered, that during the digestive process there is an erethism of the intestinal canal,—the nutritive process, all the organic actions, in short, go on with greater intensity. Hence, there is more blood elicited into the parts, and consequently the current, both in the viens and lymphatics of the intestines, will be more rapid.

contact with a living tissue. The absorption of its more fluid portion, therefore, is precisely the same phenomenon as absorption by the skin or other parts. Irritating substances applied to the arms or legs will affect the glands of the axillæ or groins; they have, therefore, entered the lymphatics as chyle enters the lacteals. But the lymphatics of the intestines are more numerous than elsewhere, they also become white by the entrance of the chyle, and they run in transparent tissues. Hence, they have been better observed. This circumstance, together with the notion that all the nutriment of the system passed along the thoracic duct, has led physiologists to regard the lacteals as a system of vessels different from all others, and as performing a function *sui generis* and utterly incomprehensible.

We have seen that the veins are the principal channels by which absorbed matters enter the circulation. They must necessarily be so, because they are more numerous, larger, and the current of the circulation in them far more rapid. Shall we deem that an exception occurs in the alimentary canal? Shall we admit that the nutritious portion of the chyme is entirely taken up by the lacteals, and that none whatever enters the veins? That the general laws of absorption are here suspended or reversed? If such a doctrine be granted, it is evident that strong and good reasons should be given therefor.

These, it is supposed, have been found in certain experiments of Dupuytren. He tied the thoracic duct in a number of horses. Some of them perished in five or six days; others recovered and enjoyed good health. In those that died, he found that injections thrown into the duct stopped at the ligature, and that none entered the subclavian vein. In those that survived and were afterwards slain, he found that the injections ran off below the ligature into branches which emptied their contents into the veins.* The obvious inference was that death occurred in consequence of the nutriment not finding its way into the system.

But there is no evidence whatever that the animals perished of inanition, for horses will live a longer time without food; and that drinks, together with the salts they hold in solution,

* Majendie's Journal de Physiologie, tom. i. p. 21.

are taken into the intestinal veins, has been proved by the experiments of scores of the best physiologists.

I take the cause of death to have been the complete interruption given to the circulation in an extensive system of vessels. By tying the thoracic duct, the lymphatics became engorged with their contents even to their capillaries; the nutritive process in the tissues was thus interfered with; morbid actions were generated and death followed in consequence.

From the experiments of W. Hunter, related by his brother, it would appear that absorbed substances do not enter the intestinal veins. Solutions of indigo, etc., were observed to colour the lacteals, but were never discovered in the blood of the veins. Passing over a criticism of these celebrated experiments, I shall merely remark that in sound philosophy, negative can never be placed in opposition to positive results, if sufficient care has been taken to avoid error. The experiments of Delille, Magendie, Segalas, Fodéra, Flaudrin, Mayer, Tiedemann and Gmelin, Lawrence and Coates, with those of many others, unquestionably prove that substances, absorbed from the intestinal canal, are sooner found in the blood, than in the thoracic duct.

Such being the case, and as the venous capillaries run through the same tissues and possess the same structure as those of the lacteals, we must admit, unless some reason can be given to the contrary, that the nutritious portion of the chyme enters the system by the veins as well as by the chyliferous vessels;—or rather, that by far the larger portion enters by the veins.

It has been urged that the mere fact of the chyle being composed in part of globules, bodies too large to pass intermolecularly through the tissues, was evidence enough to show that "their escape from the intestine could not be accounted for on the theory of imbibition or permeability of tissue; organic pores must be supposed to exist of a size adequate to their transmission."*

But are these globules really transmitted? We find the like with some variety, in pus, in milk, in the lymph, in the serum of the blood, in short, in all albuminous solutions. Can we sup-

* Owen. Note to J. Hunter's Animal Economy, p. 313.

pose these globules to be those of the blood modified by some cause or other? We cannot, since those of pus are much larger and more irregular in form. Neither could they have permeated the tissues, since the smaller globules of the blood pass directly through the capillaries from the arteries into the veins. They appear to be formed in the liquid itself by a species of precipitation effected by some unknown cause. The following extracts from Raspail throws light on this subject. "Let a certain quantity of the white of an egg be put into concentrated hydrochloric acid in excess; the albumen, at first coagulated white, will dissolve in the acid, giving it a violet colour which will afterwards pass into a blue. If the hydrochloric acid be now decanted and abandoned to spontaneous evaporation, a white powder will be precipitated, which observed with the microscope, is seen to be composed of very small globules, spherical in form and uniform in size, and which the most practised eye might easily confound with the globules of the blood."*

Again;—"We have seen that gluten, which is the albumen of vegetables, by a spontaneous evaporation of its menstruum, is deposited from its acid solution in the form of spherical globules. The same phenomenon is seen under the microscope, if we leave to spontaneous evaporation at a temperature of 10° or 12° centigrade, a watery solution of the albumen of an egg; the liquid becomes opaline and thousands of globules are observed suspended in it. It is the same with every oleaginous substance dissolved by a menstruum; as soon as the menstruum is diluted with water, or is saturated, the fatty substance is precipitated in the form of exceedingly small globules, which being suspended in the liquid, troubles its transparency and renders it opaline. This phenomenon is witnessed continually when the alcoholic solution of absynth or Cologne water is mixed with water."†

The argument derived from the existence of the globules in the lacteals, falls, therefore, to the ground.

The veins of the intestinal canal have a peculiarity in their distribution; they are, in fact, an anomaly in the system. Uniting from all sides, they at last form a large trunk, the *vena*

* Nouveaus Système de Chimie Organique, tom. iii. p. 176.

† Op. cit. vol. iii. p. 135.

portarum, which instead of entering the vena cava and thus transmitting its contents at once to the heart as other veins do, suddenly upon reaching the liver divides and sub-divides into numberless branches, which penetrate the liver after the manner of an artery. An arrangement, so unusual and yet so general, must answer some definite purpose; there must, in short, be some relation between the blood which these veins carry and the function of the liver. The following extract may perhaps throw some light upon the subject. "A gramme* of bile suddenly injected into the crural vein, causes the animal to perish in a few seconds. It is the same with a certain quantity of atmospheric air rapidly introduced into the same vein. If the injection be made in the same way into one of the branches of the vena portæ, it will produce no injurious effect. Why this difference in the results? Does the passage of the liquids, foreign to the economy, through the innumerable small vessels of the liver, cause them to mix more intimately with the blood, and to mingle with a larger quantity so that its chemical nature may be a little changed? This is the more probable, since the same quantity of bile or of air very slowly injected into the crural vein does not produce any perceptible effect."†.

It must be borne in mind that the intestines present a very large surface with which liquids, sometimes in a very fœtid state, are usually in contact. Were these fluids suddenly taken into the circulation and thrown upon the lungs or brain, serious effects would unquestionably occur. Perhaps this is prevented by the change they undergo during their passage through the liver.

Yet we must also remember that cases are reported upon unquestionable authority, in which the vena portæ entered directly into the vena cava without passing through the liver.‡

Though the liver therefore, may perform some such function as attributed to it by Majendie, the distribution of the vena portarum through it, is not essential, neither towards the secretion of bile nor the maintenance of health.

* Fifteen and a half grains avoirdupois.

† Magendie—Précis. Élément.

‡ See Dunglison's Physiology, vol. ii., Secretion of Bile.

Absorption of Oxygen and Exhalation of Carbonic acid gas by the Lungs.—Passing over the shades in the opinion of various authors, we may state the two principal theories of respiration to be as follows:—

In the first, the oxygen of the atmosphere is supposed to combine with the carbon of the venous blood and form with it carbonic acid which is exhaled as a gas. When carbon and oxygen unite, heat is given out;—animal heat, therefore, according to this theory, is formed in the lungs; but as the sudden evolution of so much heat would certainly destroy the lungs, it was necessary to suppose that the capacity of the blood for caloric underwent a change during its conversion from nervous into arterial. Arterial blood was supposed to have a greater capacity for caloric which, therefore, became latent at the moment of the change. This latent heat was supposed to be set free as the blood was reconverted from arterial into venous; and this set free at all points of the body, constituted animal heat.

But if we breathe the same air for a while, there occurs a diminution of its volume;—a real loss in quantity. Now 100 volumes of oxygen is contained in 100 volumes of carbonic acid gas. If, therefore, all the oxygen inspired was consumed in forming carbonic acid, the quantity of the latter gas expired should exactly equal that of the oxygen inhaled. But such is not the fact;—more oxygen is consumed than carbonic acid given off.

To account for this, it was necessary to suppose, that a portion of the oxygen united with the hydrogen of the blood, and thus formed the halitus or watery vapour which is exhaled from the lungs.

In this theory, therefore, arterial was the venous blood, minus, the carbon and hydrogen that united with the oxygen; and the change of colour was owing to the loss of the carbon.

The other theory supposes carbonic acid to exist in venous blood either in a state of solution or in a very feeble combination with the hæmatosine. When traversing the capillaries of the lungs, the carbonic acid is exhaled and the oxygen absorbed; both passing through the exceedingly delicate tissues which form the air-vesicles. Arterial blood, therefore, differs from venous

in possessing more oxygen and less carbonic acid. The change of colour is owing not merely to the loss of carbonic acid, but also to the influence of oxygen on the colouring matter. The halitus is mere watery vapour caused by evaporation.

But whence the carbonic acid in the venous blood? The oxygen of the arterial blood, carried along in solution or in feeble combination with the colouring matter, arrives at last in the capillaries, whence it is absorbed among the molecules of the tissues, and there performs an important part in the process of nutrition. This process, it is well known, does not in animals consist of assimilation only, but also in liquefying the solids left by processes undergone previously. In short, this process in animals is essentially one of composition and decomposition, by which some portions of the nutritive fluid are fixed in the solid state, and the old solids reduced to fluids. Now, in this reduction of the solids, the oxygen of the arterial blood is supposed to play an important part. By combination with their carbon, it forms carbonic acid, which is taken up in solution or combines feebly with the hæmatosine, turning it black; and as at the same time heat is given out, we have a ready explanation of the source of animal heat.

But the oxygen consumed is greater in quantity than is necessary to form the carbonic acid given off from the lungs. What becomes of the superabundant portion? The answer is; that the lungs are not the only organs that eliminate carbonic acid; it is found in the exhalations from the skin, and also in the secretions of the kidneys and other organs where by union with bases it forms carbonates. The quantities furnished in these ways, is supposed to make up the deficiency.

The main difference in the two theories, it will be seen, consists in this:—the first places the formation of carbonic acid in the lungs; the second, in the tissues generally.

When first proposed both of these theories were hypothetical, but investigation has nearly confirmed the latter and overthrown the former.

In the first place it has been proved beyond a doubt, by Dr. John Davy, that arterial blood, instead of possessing a much greater capacity for caloric than venous blood, scarcely differs

from it in this respect. The experiments on which he himself most relied gave him for arterial blood 913, for venous 903. In another series of experiments he found the capacity of arterial blood to be 839, whilst that of venous was 852.* These facts are sufficient of themselves to overthrow the theory first mentioned.

There is no proof whatever that a portion of the oxygen of the atmosphere unites with hydrogen to form the vapour exhaled. This vapour is beyond doubt nothing more than an evaporation, such as occurs from all exposed moist surfaces.

Carbonic acid gas has been obtained from the blood by means of the air-pump by Vogel, by Brande, by Home and Bauer, by Scudamore, by Collard de Martigny, by Clanny, and more recently by Magnus, Bertuch, Bischoff,† and by Dr. John Davy.‡

It has been shown by the experiments of Dr. W. Edwards, of Collard de Martigny, of Bergemann, and of Müller,§ that cold-blooded animals made to breathe in nitrogen or hydrogen gases, evolve carbonic acid gas in considerable quantities. This gas, therefore, must have existed already formed in the venous blood, since there was no oxygen present, and the lungs and throats of the animals were previously emptied, not only by pressure, but in some instances by the air-pump.

The experiments of Dr. Rogers also prove that carbonic acid exists already formed in the blood. I quote from his paper the following: "A small bladder, not long taken from a pig, was filled with fresh venous blood, when it was closed and suspended by a thread from the cover of a tall receiver, which fitted air-tight. The receiver standing over mercury, was then filled with oxygen, and in two hours the mercury at the bottom of the receiver was considerably depressed. Upon inspecting the contained air, a very sensible quantity of oxygen had disappeared, but was replaced by a still larger amount of carbonic

* Dr. Davy's Researches—Physiological and Anatomical, 1839. Vol. i. p. 142.

† Müller's Philosophy, vol. i. p. 326.

‡ Op. cit., vol. ii. p. 159. These are the last experiments of Dr. Davy, performed since those of Magnus.

§ Müller, op. cit., vol. i. p. 336.

acid, the excess of which explained the depression in the mercury. This experiment was varied by making trial of other gases, as hydrogen, nitrogen, and bicarburetted hydrogen; and in every case with a development of carbonic acid."*

In the experiments of Magnus, carbonic acid, oxygen, and nitrogen, were found both in venous and arterial blood, but the proportion of carbonic acid was greatest in venous, and that of oxygen, in arterial blood.†

The elementary analysis of Abilgaard, of Michaelis, and of Macaire and Marcet, have shown that carbon predominates in venous blood, and oxygen in arterial.‡

All these facts go to refute the first, and confirm the last-mentioned theory.

When venous blood is directly exposed to the atmosphere or to oxygen gas, a quantity of oxygen is absorbed and the arterial hue is produced, but no carbonic acid gas is given off.

When the same blood is directly exposed to carbonic acid gas, a considerable quantity of the gas is absorbed.

Heat applied to venous blood produces no evolution of carbonic acid gas.

Though carbonic acid gas is given off from blood under the receiver of an air-pump, yet it is not until the exhaustion is nearly complete, that the evolution takes place.

From these facts, it is obvious, that carbonic acid is retained in venous blood by a considerable attractive power, yet it is continually and freely given off from the lungs, as likewise from the thin delicate skin of many of the inferior animals.

What is the power, then, that breaks up the attraction between carbonic acid and the venous blood? It lies in the animal membrane, which constitutes the air-vesicle, which separates the blood from the atmosphere, and with which both the air and blood are in immediate contact. The experiment of Dr. Rogers, already cited, sufficiently proves this,—we learn from it that blood, *placed in a bladder*, evolves carbonic acid gas though the surrounding gas be hydrogen or nitrogen. It

* Experiments upon the Blood, etc. American Journal of the Med. Sciences. No. 36. August, 1836.

† Müller's Physiology, vol. 1st. p. 327. ‡ Müller, op. cit. vol. 1st. 323.

had been long before shown, by Dr. Faust, that carbonic acid gas was evolved from blood contained in a bladder and exposed to oxygen gas.*

The absorption of oxygen and the exhalation of carbonic acid gas are, therefore, perfect cases of endosmose and exosmose. Carbonic acid gas is absorbed from the blood by the membrane, which in turn yields it to the atmosphere of the lungs. Oxygen is likewise absorbed by the membrane from which it is taken by the blood.

A question may be asked, why is not nitrogen also absorbed? Simply because it has a relation with the tissues different entirely from that which oxygen and indeed most other gases hold. By referring back to the tables of Dr. Mitchell, it will be seen that " nitrogen has a rate of penetration so low as to be difficult to ascertain, because there is no gas of a lower rate with which to compare it. Only by causing it to pass through a membrane by means of a column of mercury, is the fact of its transmission known."†

Interstitial Abscrption.—" The various phenomena of excretory absorption, as it may be termed, under the theory of the capillary attraction of the tissue, whether of veins or lymphatics, as their cause, are equally unsatisfactory. A property of dead matter cannot account for the rapid absorption of fat in disease; or of the parts of muscles, etc., which, from some accident to a joint, have become useless; or of alveoli of shed teeth; or of the parts which in the progress of growth become inconveniently situated, as the first deposite of osseous matter in long bones; or of parts which, at the conclusion of growth, are equally inconveniently situated in regard to some tumour or collection of matter, the discharge of which is salutary to the constitution, etc. A mere physical endowment of animal tissues ought always to be acting, and acting in but one way; and we therefore conclude, with Hunter, that these various and partial operations of the lymphatics are effected by the vital actions of organic pores, in a manner analogous to that which determines in lacteals the exclusive absorption of chyle."

* Amer. Journal of the Med. Sciences, vol. 7. † Ibid.

The above remarks are by Mr. Owen, and appended to the last edition of John Hunter's works to his paper on absorption by veins. I pass over the latter part of his remarks, leaving the subject to those who understand what is meant by the "vital actions of organic pores."

As to the rest, he has evidently confounded two very distinct things;—absorption, properly speaking, and liquefaction of the solids, which is a result of the nutritive process.

For I fancy that if the matter be rightly understood, the explanation of interstitial absorption, as it is called, will not offer any peculiar difficulty. As said above, there are two processes which must be distinguished—first, the resolution of the solids into fluids; and secondly, the removal of those fluids after being formed. The process of nutrition in animals, as has been mentioned more than once, consists not only in the assimilation of the nutritive fluid,—the conversion of portions of it into solids,—but likewise in the reconversion of the solids into fluids. Were this not the case, there would be no cessation to growth until life was extinct.* In early life more of the nutritive fluid is assimilated than solids removed; in the adult, the loss and deposition of materials seem to be equal; in old age, more is removed than deposited. But throughout all the living existence of an animal, the two processes—or rather, the two effects of the same process, are continually going on. The old experiment of giving young animals madder proves this.

If then, a portion of the solids be converted into fluids, it is obvious that those fluids are in precisely the same condition as fluids introduced into the tissues from without. They will, therefore, be subjected to the same laws;—be absorbed through the tunics of the capillary vessels and thus swept into the vortex of the circulation, or be thrown out as a secretion.

In this process, as well as in that wherein the liquor sanguinis is absorbed from the capillaries into the substance of the tissues, may not the membranous tunic of the capillaries be, as in the lungs, essential to the effect? Nutritive action takes place *extra vasis*, among the very molecules of the tissues;—before the nu-

* This is really the case with vegetables.

tritive fluid can act, it must be absorbed from the capillaries;—the results of this action are, in part, returned to the capillaries;—hence there seems to occur a true endosmosis and exosmosis through the coats of the capillary vessels.*

Power of Selection.—Certain facts have induced some physiologists to admit the existence of a power in the tissues of plants and animals, of selecting as it were, certain portions of fluids presented to them, and of rejecting others. This is not exactly true; but unquestionably the rapidity with which a fluid is absorbed will depend not only on the nature of the fluid, but also greatly upon the constitution of the absorbing tissue.

The leaves of plants under the influence of light, absorb carbonic acid and exhale oxygen;—the lungs of animals do exactly the reverse.

If a bean and a grain of wheat be sown side by side, silica will be found in the stem of the wheat, but none in the bean.

The same plant grown in soils entirely different will always contain salts and very nearly in the same proportion.

We have seen that oxygen is absorbed rapidly by the lungs, but that scarcely any nitrogen is taken up.

In cases of exhalation which is, in part, absorption reversed, we find differences apparently unaccountable. Thus in certain cases, the albuminous portion of the blood is effused; in others, fibrin; in others, serosity, mixed with hæmatosine, etc.

But if there exist a power of selection, how is it that both plants and animals greedily absorb substances which are fatal to their existence? Both will absorb solutions of opium, arsenic, the salts of copper and other substances, all at war with their well-being.

As for the same species of plants possessing always the same salts, though they be grown in different soils; or of plants of different species, possessing different salts though grown in the same soil, it must be borne in mind that there are salts, which,

* The like also occurs in plants;—the nutritive fluid is first absorbed by the walls of the vesicles of which plants are made up, and the matter contained in the vesicles, if it be fluid, transudes outwardly. The nutritive process occurs in the walls of the vesicles.

like the carbonate and phosphate of lime in bones, enter into the very composition of the tissues of plants. And these salts are different in different kinds of plants. Thus silica is a component part of the tissue composing the stem of wheat, but does not enter the tissues of the bean as a component. Hence it is that if these substances be present in the soil, they will not only be absorbed, but will become fixed in the plant and form a portion of it. But this by no means proves that other plants do not absorb the same substance; nor that the same plant does not absorb other substances.

When alcohol, laudanum, iodine, quinine, etc., are taken into the animal economy, what is their ultimate destination? They do not become fixed in the tissues; they form no part of them; but in a few days entirely disappear from the body, having been thrown off by some of the emunctories. Yet we find other substances are appropriated by the tissues—combine with the albumen (the original base of the tissue) and become a part of them. The same thing happens in plants;—the substances which they absorb and which are not necessary for their nutrition, are thrown off by excretions from the roots.

"When," says Liebig, "the soil in which a white hyacinth is growing in the state of blossom, is sprinkled with the juice of the fruit of the *Phytolacca decandra*;* the white blossoms assume, in one or two hours, a red colour, which disappears after a few days under the influence of sunshine, and they become white and colourless as before. The juice in this case evidently enters into all parts of the plant, without being apparently either necessary or injurious. But this condition is not permanent, and when the blossoms have become again colourless, none of the colouring matter remains; and if it should occur, that any of its elements were adapted for the purposes of nutrition of the plant, then these alone would be retained, whilst the rest would be excreted in an altered form by the roots.

"Exactly the same thing must happen when we sprinkle a plant with a solution of chloride of potassium, nitre, or nitrate of strontia; they will enter into the different parts of the plant,

* American nightshade.

just as the coloured juice mentioned above, and will be found in its ashes if it should be burnt at this period. Their presence is merely accidental; but no conclusion can be hence deduced against the necessity of the presence of other bases in plants. The experiments of Macaire Princep have shown that plants made to vegetate with their roots in a weak solution of acetate of lead, and then in rain-water, yield to the latter all the salt of lead which they had previously absorbed. They return therefore to the soil all matters which are unnecessary to their existence. Again, when a plant, freely exposed to the atmosphere, rain, and sunshine, is sprinkled with a solution of nitrate of strontian, the salt is absorbed, but it is again separated by the roots and removed farther from them by every shower of rain, which moistens the soil, so that at last not a trace of it is to be found in the plant."*

We must, therefore, draw a marked distinction between substances which enter into the composition of the tissues or nutritive fluid, and others accidentally introduced.

But that there really is a difference in the attractive force of substances for each other, although no chemical union or change may ensue after contact, is, I think, beyond question;—and herein the mathematicians, by assuming the contrary, have committed an egregious error. By referring to the explanation of Poisson concerning the phenomena of endosmose and exosmose, it will be seen that he argues as if the constitution of the intervening membrane went for nothing in the account; and it was herein that he failed to explain the facts.

Proofs lie around us in abundance to rebut such a view of the subject. Even the phenomena of capillary attraction disprove it; for we have seen that water will rise in a glass tube, whilst mercury will be depressed. Water, again, will take up in solution more of one salt than of another. It will absorb more of one gas than of another; and this is exemplified even with regard to the atmosphere, for the air extracted from rain-water contains 32 per cent. of oxygen, whereas the atmosphere contains but 21 per cent. Hence water has a greater attraction

* Liebig's Organic Chemistry, p. 156, Amer. Edit.

for oxygen than for nitrogen, and for carbonic acid than for either.

The like facts have been brought to light by experiments upon endosmose and exosmose. Carbonic acid, though the denser gas, is absorbed far more rapidly by animal membranes than atmospheric air or even oxygen is absorbed;—so much more indeed, that if a bladder containing but a small quantity of oxygen be immersed in an atmosphere of carbonic acid gas, the latter will enter and distend the membrane even to bursting. Again, if an *animal* membrane be used, water will penetrate it in a greater ratio than alcohol, but if the membrane be of *gum-elastic*, the alcohol will be transmitted in the larger proportion.

Now the same principles must be applicable to absorption in living beings. The spongiolæ of the roots of different plants are not constituted alike; they will, therefore, though growing in the same soil, respectively absorb, some more of one, some more of another salt. Hence the chemical constitution being entirely different, the membrane of the leaves of plants absorb carbonic acid, whilst that of the lungs absorb oxygen. Hence, too, very little nitrogen is absorbed, either by the leaves of plants or by the lungs. By referring to the experiments of Mitchell, it will be seen that nitrogen is the lowest of all the gases in its powers of penetration through membranes,—so low indeed, that it could not be estimated.

Disease essentially involves a change in the condition of the tissues, and according to the nature of this change, combined with other circumstances, shall we have, in one case, effusion of lymph; in another, of semen; in another, passive hæmorrhage, etc.

Unquestionably the elective affinity which bodies display towards each other is an inscrutable mystery; but it is one common to both the inorganic and organic worlds. We cannot grant that the tissues of an animal, or the roots of plants, exercise an *intelligence* when they absorb more of one salt than of another, any more than we can grant the same to the components of muriate of soda when it decomposes nitrate of silver, or to any other agent of chemical decomposition.

Influence of Nutritive Action upon Absorption.—The nutritive

fluid, in the lower orders of life, is absorbed directly into the tissues without passing into vessels of any sort; this is the case with the cellular vegetables, and with many of the radiata, such as the Hydra, etc. In the higher orders of life, it is absorbed by the tissues from the capillary vessels, penetrating the tissue intermolecularly, acting upon them and being acted on in turn. This action is essentially chemical, and it consists in the transformation of some portions of the nutritive fluid into solids, and the resolution of old solids into fluids. The remaining portions of the nutritive fluid, as soon as the change is effected, is removed from the spot, (either as venous blood or as a secretion,) and its place filled up with a fresh supply of nutritive fluid. The removal of the fluid that has undergone the change, is assisted in the higher animals by the action of the heart; but neither the heart nor any other mechanical power is absolutely necessary for this effect, since the same thing occurs in plants, and in animals without hearts. The cause of the removal is, beyond question, the chemical action going on in the tissues; for we may state this proposition as a truth;—that whenever a chemical action occurs in the midst of fluids, by which action a portion of the fluid is chemically altered, but without losing fluidity, there will be a strong current *to* the spot, and another, *from* it. The first will consist of the fluid to be changed; the second, of the fluid which has undergone the change. The first current will in fact displace the second.

In that condition of the body we term health, there is always a great quantity of the nutritive fluid in the tissues, that is, *extra vasis*,—drawn thither by the power of the nutritive process. When this process is diminished, the current into the tissues becomes less rapid; and in warm-blooded animals, the tissues contract from their elasticity, and pallor and coldness of the parts ensue. When it is increased, the opposite effects take place;—we have swelling, heat and redness of the parts. But these things have already been sufficiently dwelt upon.

THE END.

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FIG. 4.

FIG. 5.

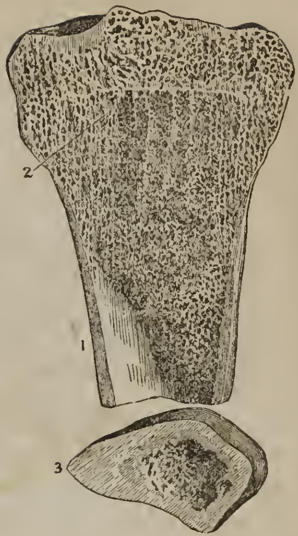

FIG. 6.

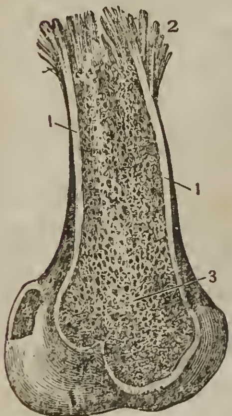

FIG. 7.

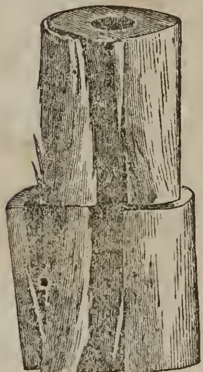

FIG. 4.

A Longitudinal section of a Femur, showing the Cellular Structure at its extremity.

FIG. 5.

A Longitudinal section of a Tibia, showing

1. The Compact Structure.
2. The Cellular Structure.
3. A Transverse section of the Femur, showing its Compact Substance, its Internal Cellular Structure, and the Medullary Canal.

FIG. 6.

The Texture of a Bone as shown in a Humerus, after maceration in dilute acid.

1\. 1. The Compact Matter as usually seen.

2\. 2. The same split, so as to show the Longitudinal Fibres composing it.

3\. The Internal Cellular Matter.

4\. The Bone seen under its Articular Cartilage.

FIG. 7.

A view of the Concentric Lamellæ of the Compact Matter of a Bone.